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SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed at Aberdeen in 1925 and adopted its first Constitution at Oxford in 1926. This has been modified several times and the present Constitution became operative in December 1947.

The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects. It is intended that the Society should be representative of the profession. Those not engaged in the practice of forestry or the allied sciences are cordially invited to join as Ordinary Members.

The activities include the publication of the journal, the holding of meetings, conferences, and excursions, and the awarding of a medal.

THE SOCIETY'S JOURNAL, called *Forestry*, is published twice a year, in May and November. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure, and timber physics, and allied sciences such as forest entomology and forest mycology.

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[*continued on inside back cover*

PLATE VI

FORESTRY IN PERTHSHIRE: NOTES ON PAST HISTORY

By J. L. F. FERGUSSON

(*Forestry Commission*)

SUMMARY

The paper deals shortly with the era of destruction; the attempts at preservation as times became more settled; the first plantings; and then with the development of commercial forestry down to modern times. There is a useful bibliography.

IN olden times the great Caledonian Forest covered much of Perthshire. On the higher ground and poorer soils, Scots pine (*Pinus sylvestris* L.) and birch (*Betula* spp.) were the main species, with oak (*Quercus* spp.) dominant in the lowlands and river valleys, often also mixed with birch. Ash (*Fraxinus excelsior* L.) and alder (*Alnus glutinosa* Gaert.) occurred in damp sites. The oak was mostly, if not entirely, the sessile species (*Quercus petraea* (Matt.) Lieblein). The more easily cultivated land was cleared first and, as the population increased, the pressure on the remaining forests, harbours for robbers, wolves, and other enemies of the flocks, became progressively greater. Fire must have been a potent instrument in the destruction of the forests, more so in early days than the adze. The original extent of tree growth can be judged by the presence of pine trunks and roots in the peat, not only of Rannoch Moor but elsewhere, and of oak logs in lowland swamps and alluvial deposits.

The Roman legionaries under Severus are said to have cut down much of the forest about A.D. 200. So, in their turn, did the Danes. John, Duke of Lancaster, is supposed to have employed 24,000 axes on the work of clearance, and an order by General Monk dated 16th May 1654 caused the Earl of Airth to cut down woods near Aberfoyle which were sheltering rebels (17).

There came a time, however, when the rulers of Scotland had to pass legislation to preserve the woods and encourage planting. For example, an Act of King James I ordained a fine of forty shillings on persons who 'steallis green woode or peallis the bark off trees or destroiard woodes', and others in the reigns of James II (1457), James IV (1503), and James V (1535) ordained the planting of trees and hedges (15). A warrant under the seal of James VI allowed Ure Campbell of Strachur 'to mak plant big and repair and fre forrest in his lands and barony of Glenfalloch . . .' (21). *The Black Book of Taymouth* (16) says that Sir Duncan Campbell of Glenorchy 'caused make parks in Balloch, Finlarig, Glenlochay and Glenorchy, and caused sow acorns and seed of fir therein, and planted in the same young fir and birch in anno. 1613 and 1614'. He also made penalties for destroying trees, caused his tenants and others to plant three or six trees yearly, oak, ash, or plane, the gardener to supply the trees, and made it an offence to carry out muirburn without six honest neighbours being present.

PLATE VI (*opposite*). Dunkeld and larch plantations on Atholl estate. (*By permission, Aero Pictorial Ltd.*)

In the early days the monastic houses either owned extensive woodlands or had the right to take wood from certain areas owned by the feudal lords. In 1200 Earl Gilbert founded the Abbey of Inchaffray and allowed the monks to take from his woods timber, bark, and fuel, with right of pannage (18). Before 1250 Conan of Glenorchy, son of Henry, Earl of Atholl, gave the monks of Lindores Abbey the right to take dead wood, hazel (*Corylus avellana* L.), &c., from the 'wood of Tulyhen', and from the wood of Glenorchy and Tulloch. Sir Fergus of Fedal also gave them a similar right in his wood. The wood of Glenlithern is mentioned; this glen runs from Braco and Ardoch in a north-westerly direction towards Comrie (7). William the Lion gave the monks of Coupar Abbey (Coupar Angus) in 1171 his chase of Campsie, on the Tay, for timber for building the abbey. There are clauses in later leases of this wood insisting on the planting of trees and protection against stock, and the gardeners at the abbey were bound to keep eleven beds of young trees, each 24 feet long, to weed and feed them until they were 4 years old and ready to set out in the plantations. In 1471 the forest was divided into four parts, which were later walled. In 1473 one Neil McKeden was appointed master forester of all the abbey's woods in Strathardle. In 1470 two keepers of the Forest of Forter (in Glenisla) were allowed to keep cattle in the clearings, and about the same date the woods of Murthly in Athole and Inverack were inclosed (13). All these belonged to Coupar Abbey. Later, considerable woodlands around Dunkeld belonged to the Bishops of Dunkeld. The writer of the New Statistical Account in 1842 for Dunbarney parish says that in Sir William Wallace's day the ancient forest of Black Earnside used to extend for 4 miles by 3 miles along the banks of the Earn (6). No doubt the Lindores monks had rights there also.

It is doubtful if the various Acts of Parliament of 500 to 300 years ago were at all effective in preventing the destruction of the forests or in encouraging planting on any scale, but, all the same, the more remote areas of natural forest remained fairly extensive for a considerable period. The first attempts at planting were on a small scale around the lairds' houses and they increased as times became more settled. At first native hardwoods and Scots pine were used, and then sycamore (*Acer pseudoplatanus* L.) and European silver fir (*Abies alba* Mill.) were introduced. Probably the first extensive planting on silvicultural lines in Scotland was carried out by Sir Duncan Campbell of Glenorchy on Drummond Hill and around Taymouth Castle from 1583 to 1631. He used mainly oak, birch, and Scots pine, seed for the last being collected from natural stands on his property. Early in the eighteenth century about one-third of the south slope of Drummond Hill was planted, but even at that time commercial planting was quite uncommon in Scotland.

There are records of the Earl of Lauderdale and the Marchioness of Hamilton obtaining pine seed from Campbell of Glenorchy about 1637 (16). In 1684 or 1685 the Marquis of Atholl's men cut the growing wood in Glen Aray on the property of Campbell of Argyll and carried back to Atholl large numbers of young trees including hollies, 'silver and Spanish firs, pinasters' and so on, for which the sum of £16,000 Scots (£1,336 sterling) had to be paid later on (2).

There was evidently some planting carried out in Strathearn in the latter half of the seventeenth century, because Richard Pococke, Bishop of Meath, who made tours in Scotland in 1747, 1750, and 1760, refers to the Earl of Perth who was Chancellor to James the Second (of England) as having made 'these great plantations of several kinds of firs, also of beech, sycamore and many other sorts of trees. Some of the spruce firs are three feet in diameter' (23).

The system of coppice with standards was practised in these woods at an early date and continued up to the end of last century on a comparatively well-managed basis. Hunter (15) states that in the marriage contract of Sir James Stirling in 1606, his father, in settling on him the estates of Keir and Cawder, reserved the power of cutting down the woods of Keir, Cader, and Brokland. Hunter also quotes from a rent roll of Keir and Cawder, 1632, that 'the laird has three woods, viz. the Wood of Keir, the Wood of Cader and the Wood of Brokland, which within short space will be worth the sum of ten thousand pounds money, which woods were cut 20 years ago by Sir Archibald Stirling, who got at his last selling of them eight thousands, besides the Ladies' part'. In his Working-plan Report on the Keir Woods, 1907, Fisher (11) says that the oak coppice in the Wood of Keir had been cut every 21 years since 1590. The yield when he wrote was 30 cwt. of bark per acre and 4 tons of firewood. The bark sold for £4. 15*s.* per ton and the firewood for £1, giving a net return of only £6. 5*s.* per acre every 21 years. Oak tan-bark had by that time ceased to be a very paying proposition, owing to imported extracts.

Edlin (9) has described this oak coppice system recently in *Scottish Forestry* and noted how extensive it was in Perthshire and Argyllshire particularly, and how valuable the tanning bark. The wood from the coppice poles was used mainly as fuel and for farm purposes, but in the days before coal was freely available much charcoal was made for use in the iron furnaces. Macfarlane (20), a traveller writing in the early eighteenth century, refers to a new ironworks near Callander for which the charcoal was obtained from a large birch wood nearby. The writer of the New Statistical Account for Callander (27) parish mentions a rotation of 16–20 years for oak tan-bark, and the figure of 18–20 years is mentioned for the wood of Craighall, Blairgowrie (19). In 1794 those in Callander parish were said to be worth as much as £15,000 at every cutting, every 24–25 years (24) In 1798 the writer of the account for Dunkeld parish (30) says that the price had increased lately and that the Wood of Guay, disposed of by roup (auction) had made the following prices per acre: first sale—£166, second sale—£551, third sale—£1,262. The average was about £40 per acre. The peelers received 1*s.* per day in the case of men and the season lasted from May to July. Birch became much less valuable and, in 1794 in Little Dunkeld parish, the 200 acres of birch woods were said to be not worth above £2 per acre at 22 years (26).

Many of these oak woods can be seen in West Perthshire and between Dunkeld and Pitlochry, and are recognizable as having been coppice with standards, some having been so worked in the first quarter of this century, but they are now generally classed as scrub (12). The oak is generally sessile but pedunculate oak may occur. Perhaps this may be due to the practice of planting up blanks in the

coppice. The New Statistical Account for Methven parish (5) mentions Methven Wood of 260 acres being chiefly of pedunculate oak and that '*Quercus sessiliflorus* is not indigenous here'. It had been worked as coppice for some hundreds of years. In the 1794 Account (8) it is stated that the hazel there had been let at a rent of £12 to a coal company for above 20 years. In the first part of the nineteenth century oak was still being planted at Scone (in mixture with conifers) with a view to its use for 'copse'.

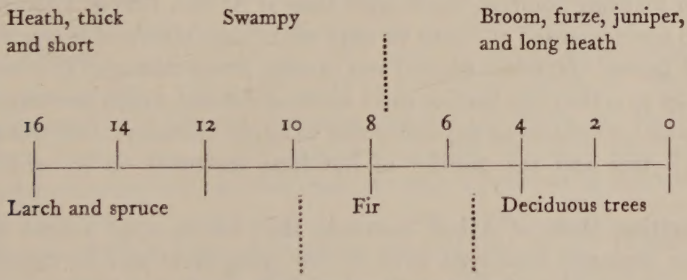
Sufficient has been mentioned to show how the oak woods survived from ancient times under repeated coppicing, although they appear to have been protected from browsing for only about 6 years after cutting, in many places. What of the old native pine forests? There were extensive remnants in the north-west of the county, but for a century and a half, at least, only the Black Wood of Rannoch, on the south side of the loch, has remained as a considerable forest. At the beginning of the nineteenth century its area is quoted as 2,566 acres, but that may be an over-estimate (25). Whayman (33) has recently given an account of its history in *Scottish Forestry* and suggests that it escaped destruction in the early days because it gave protection to the inhabitants. It must have been a considerable source of revenue to the Robertsons of Struan, as the timber was in great demand owing to its lasting quality. Splints of the resinous 'Rannoch fir' were also much used for domestic lights. Other meagre remnants of natural pine forest occur in Glen Lyon, but in 1763 mention is made of a 'very great Fir Wood' in that glen having become quite exhausted 'owing to extending the hagges (yearly cuttings) to a greater extent than it could bear' (quoted by Whayman).

It seems evident that nearly all the planting done up to the end of the seventeenth century was on a small scale and mainly for amenity and shelter, although that at Drummond Hill was perhaps an exception. Apart from coppice working there was little or no forestry for commercial purposes. The eighteenth century, however, brought an increasing interest in commercial planting and certain exotic trees were introduced. Planting was encouraged and awards given by such bodies as the Society of Improvers, founded in Edinburgh in 1723, the Edinburgh Society of Arts and Manufactures, and the Highland Society, founded in 1784. The Perth Nurseries were founded about 1767 by John Dickson of Hassendean, Roxburghshire, and covered 30 to 40 acres in 1796. They continued to supply many kinds of forest and fruit trees for about a century and a half. At first oak, ash, sycamore, birch, beech (*Fagus sylvatica* L.), and Scots pine were the main species used, the oak being the 'English oak' (*Quercus robur* L.), which was preferred on account of the better supply of acorns and the evident larger size of that species in the south. The writer of the Statistical Account for Scone parish, 1796, mentions the figure of 700 acres under plantations, most of the old wood having been planted about 1720–30 (32). Planting at Drummond Hill continued up to the start of the nineteenth century and Menzies of Culdares, who owned most of Glen Lyon, planted the Black Wood of 127 acres in that glen in 1730–40, mainly with hardwoods. At Lawers, near Comrie, planting of a 60-acre inclosure was carried out in 1731 (15).

The introduction of the European larch (*Larix decidua* Mill.) to Scotland was to have a great influence on commercial forestry, although the species was not planted on a large scale for about half a century afterwards. Michie in *The Larch* (22) says that the tree was introduced to Blair Drummond in 1734. The story of its introduction to the Atholl Estates is well known; some plants were brought from England in 1737 by Menzies of Culdares, a few were left at Monzie, near Crieff, where three remain today, and the rest were planted in 1738 at Blair Castle and near Dunkeld Cathedral. Today nine are still growing at Blair and one at Dunkeld.

Between 1740 and 1750 James, Duke of Atholl, planted 350 larches at Dunkeld and 873 at Blair Atholl, and in 1759 he planted 700 larches, mixed with other trees. John, the third Duke, planted some smallish areas of pure larch and further areas of mixed plantings. Plants were scarce and only about 50 larch were used per Scots acre, mixed with about 4,000 per acre of pine and hardwoods. He had planted about 410 acres by his death in 1774.

John, the fourth Duke, was rightly known as 'The Planting Duke', as during the 56 years from 1774 to his death in 1830 he is reckoned to have planted 15,573 imperial acres with 27½ million trees. He made numerous notes about his planting work and methods, most of which were summarized by his Trustees and published in the *Transactions of the Highland Society of Scotland* in 1832 (1). He was concerned about the shortage of oak for Navy timber and had tests carried out which proved that larch was in many ways a better timber for the purpose. He planted increasing amounts annually with pure larch as the supplies from the nurseries became better and extended the elevation of his plantations gradually higher, using Norway spruce (*Picea abies* (L.) Karst.) in the wetter hollows and Scots pine sparingly. The following is his diagram for 'mountain planting', somewhat simplified



(Scale in hundreds of feet elevation)

In 1815 the Duke developed the spear planter for slit- or notch-planting, enabling seedlings to be used which cost 2*s.* 6*d.* per 1,200, whereas transplants cost 10*s.* He considered 2,000 trees per acre enough. The Loch Ordie area of 2,932 Scots acres was planted from December 1815 to December 1818 at a cost of 16*s.* 8*d.* per acre, or a total of 50*s.* per acre including all incidents such as roads, fences, and the value of the land at 25 years purchase. The Loch Hoishnie area was planted in 1825-6 at 15*s.* per acre. The Duke reckoned that thinnings should

bring a return of £7 per acre and that the last thinning should be at 30–35 years of age, leaving about 400 trees per acre for final crop, which should average 50 cu. ft. per tree, and at 1*s*. per cu. ft. realize £1,000 per acre at 72 years. This estimate of final volume per acre of 20,000 cu. ft. was obviously far too high, but he no doubt based it on the growth of widely spaced old specimen larches.

Tay fishing boats were built of larch in 1777. The naval store ship *Serapis* was repaired with larch in 1800, which was so successful that the frigate *Athole* was built entirely of that timber about 1816–20. The Duke also laid great stress on the way larch litter improved the grazings by the encouragement of *Holcus* grass, so that land worth only 9*d*. to 1*s*. would become worth 10*s*. per acre at least.

In the early part of the nineteenth century, while large areas of pure larch were planted on the Atholl estates, it was more often the case elsewhere that larch was planted as a nurse for hardwoods. A book of plans and descriptions of the Earl of Mansfield's woodlands, prepared in 1822 (3), gives details of this mixed planting. Sometimes the ground was trenched by hand (£4. 15*s*. per acre is mentioned) and sometimes it was ploughed, left fallow over one summer, laid up in 4-foot ridges and planted the next winter. These ridges can still be seen in some of the Scone woods. There was a tendency to take in old arable land and that was the method of dealing with it. Oak was the main hardwood used, sometimes with beech, ash, or elm (*Ulmus glabra* Huds.), and larch was usually planted in alternate lines with them. Spacing seems to have been from 4 to 6 feet, and thinning out of most of the larch seems to have taken place quite early, at about 13 to 15 years. Sometimes the oaks were thinned in order to produce coppice with standards. For one oak/larch plantation, planted in 1804–5, Lord Mansfield received the Gold Medal from the Society for the Encouragement of Arts.

The usual method of planting was pit-planting, and at 2,190 trees per Scots acre this cost 45*s*. 10*d*. per acre in 1844. Soon after this the T-notch became more general for planting conifers, much later than at Atholl. Part of a recently felled pine wood was replanted at Scone in 1842 with Scots pine and it was found that the 'wood beetle' (*Hylobius abietis*) was causing much damage. The bark peelers were put on to collect the beetles and a method devised which prevented further damage, which would be an expensive one to apply nowadays. Soil was smoothed round each tree and the powder of hot lime scattered on it, which proved effective.

The Planting Duke of Atholl mentions that before 1795 a kind of 'blight' (aphis) had damaged European larch in low lying areas and he rightly advised against planting larch in such sites. Larch canker was also noticed at an early date and 'atmospheric disease' is mentioned as having been so bad in a larch plantation at Taymount in 1838 that part had to be clear cut at about 25 years old (3). Heart-rot of conifers seems to have been noticed on old arable sites and elsewhere early in the nineteenth century also. Rabbits were quite local in Perthshire in the eighteenth century and there is mention in the Statistical Account for Dowally parish, 1798 (30), of a rabbit warren 2 miles to the west of Dunkeld on the Atholl estate let at £25 sterling annually, and that 125 dozen was the average kill, skins being valued at 6*s*. per dozen and the bodies at 5*d*. per pair. In hard weather

green branches had to be given to the rabbits to prevent damage to young trees. In the New Statistical Account for Blair Atholl parish the rabbit, squirrel, and rat are stated to have recently made their way into the country (31). At Balvaird in 1823 rabbits did much damage in heavy snow.

Thinning seems to have been well enough understood in the early days of commercial forestry. It was practised properly at Atholl and on the Mansfield estates, as has been mentioned. The main uses for the small material were for farm purposes and firewood but sometimes the bark of larch thinnings was used for tanning purposes. A pine wood at Scone planted about 1777–87 had been thinned since 1804 and the thinnings 'paid exceedingly well for coal pitt props' (3). This use became increasingly important for estates near to the coalfields. The writer of the New Statistical Account for Methven parish (1837) comments that 'the management of plantations is better understood than formerly, when the error of planting too thick and neglecting to thin in time operated injuriously against the rearing of timber trees' (5).

While the principal species planted in the first half of the nineteenth century were oak, Scots pine, and larch, with some other hardwoods and Norway spruce, the discoveries of Menzies, David Douglas (a native of Scone) and others brought an increasing interest in North American conifers. Two Douglas firs (*Pseudotsuga taxifolia* (Poir) Rehder) were planted in 1834 at Lynedoch and one at Scone, and a Sitka spruce (*Picea sitchensis* (Bong.) Carr.) was planted at Keillour in the same year and blown down in 1920. At Murthly two early sitkas still stand; in 1954 their heights were 155 feet and 160 feet, and their volumes 950 cu. ft. and 780 cu. ft. Hoppus measure. *Tsuga heterophylla* (Raf.) Sarg., *Thuya plicata* D. Don, *Abies grandis* Lindl., and *A. procera* Rehd. were among the other exotic timber trees planted at Murthly.

While these North American exotic conifers were at first merely planted as specimen trees, as time went on they were tried in commercial plantations; one of the first of such stands was the Douglas firs planted about 1849–50 on a gravel terrace at Murthly Castle, although these were planted at wide spacings. This is quoted as having had a volume per acre in 1938 of 22,100 cu. ft., which seems a considerable over-estimate, and the mean tree was 130 cu. ft. (4). In the 1939–45 War at least 50 per cent. of the trees were cut out, but those which remain are still growing and one was 160 feet high in 1954. Those cut in the war averaged 270 cu. ft. per tree.

Another well-known Douglas fir plantation was that on the Taymount estate, 9·69 acres in extent, planted in 1860 mixed with European larch in the proportion of one to three from seed collected from the original Douglas firs at Lynedoch. The larches became cankered at an early date and were removed in thinnings. Schlich described the measurements of this plantation in 1888 (28) and did not consider the species likely to produce more solid wood during the first 30 or 40 years than the larch, nor probably than the Scots pine, a surprising statement. Scott took detailed measurements in 1912 (29), when the volume per acre was 6,044 cu. ft. Hoppus measure, the average volume per tree 40·5 cu. ft. and the mean annual increment 146 cu. ft. It had 6,352 cu. ft. per acre in 1919 (14) at

the age of 59 years and was felled in 1927, having blown down in the gale that winter.

Tsuga heterophylla was also planted as a forest tree at Murthly, in particular in the well-known stand at Rohallion, which was planted on bracken-covered grassland in 1905 after a crop of oats had been taken. In 1953 there was a standing volume per acre of 7,500 Hoppus feet where lightly thinned (B grade) and 5,100 Hoppus feet where crown-thinned (L/C grade), but in the latter case another 5,100 cu. ft. had been removed in thinnings.

From the turn of the century Japanese larch (*Larix leptolepis* (Sieb. & Zucc.) Murr.) was also planted to a considerable extent. A plot planted about 1902 at Ardchullary had 3,100 cu. ft. per acre in 1952 and rather more than that volume had been removed in thinnings. This species, however, has not achieved the popularity in Perthshire of the hybrid larch (× *L. eurolepis* A. Henry.), which arose by chance at Dunkeld in 1904 when seed was collected from some of the original Japanese larches and was due to pollination by some old European larches nearby. The hybrid larch has been discussed recently in *Forestry* by Edwards (10). The vigour and canker-resistance of this tree soon led to its large-scale planting on the Atholl estates in place of European larch. In 1953 a sample plot in hybrid larch planted in 1908–9 gave a standing volume per acre of 2,738 cu. ft. Hoppus measure, 4,422 cu. ft. having been removed in thinnings

Sitka spruce did not become a popular forest tree in Perthshire until more recently and there are no old stands of any size over about 40 years of age, but younger stands are fairly frequent, especially in the western part of the county.

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EXCURSION, 1956

The headquarters for the excursion this year is to be at Dunkeld from the 24th to the 28th of September. The annual general meeting will take place during the excursion. Mr. Frank Oliver is in charge of the excursion and the following details are available. Assemble Dunkeld on the 24th. On 25th, visit Atholl Estates (Blair section) and Faskally. The 26th, Rossie Priory, Balgowan Mill, Ledmore nursery, and Murthly (tsuga plot). The 27th, Drummond Hill, with a technical discussion after tea and dinner. The 28th, Dunkeld (parent larches).

ARTHUR GEORGE TANSLEY: AN APPRECIATION

By E. C. MOBBS

SIR ARTHUR TANSLEY, F.R.S., died on the 25th November 1955, at his home at Grantchester, Cambridge, at the age of 84. A scientist of very wide interests, he will be remembered most for his contribution to the study of plant ecology, in which he was an outstanding pioneer and leader.

From Trinity College, Cambridge, where he obtained first class honours in botany, he went to University College, London, as demonstrator in 1893, but in 1906 he was back at Cambridge as university lecturer in botany and, apart from a period in 1919 when he studied under Freud at Vienna, stayed there till 1927 when he went to Oxford as Sherardian Professor of Botany. He held this post till his retirement in 1937; a retirement that proved to be almost as active and productive as his younger years.

He very early became interested in the study of plant communities, and became a member of, and soon the spokesman for, The Central Committee for the Survey and Study of British Vegetation, founded in 1904, and was a contributor to and editor of that excellent little book *Types of British Vegetation*. In 1902 he founded *The New Phytologist*, of which he was editor for 30 years. In 1913 he became the first president of the British Ecological Society, which was founded largely at his instigation, and for 21 years he was editor of *The Journal of Ecology*. Through this journal and by his other writings, particularly the book *Aims and Methods in the Study of Vegetation* (1926) by himself and the late T. F. Chipp, as well as by his lectures and in many other ways, he has exercised great influence on the development of ecology both in Britain and overseas. The culmination of his ecological studies was the publication of his monumental work *The British Isles and their Vegetation* in 1939, which won for him the gold medal of the Linnaean Society. The book was at once universally acclaimed, and has already become a classic.

Tansley had wide scientific interests apart from ecology. His study under Freud was followed in 1920 by his book *The New Psychology*, and later *The Values of Science to Humanity* (1942) and *Mind and Life* (1952) demonstrated his analytical mind and his concern with the place of man in the scheme of nature.

After his retirement from Oxford, Tansley was president of the Council for the Promotion of Field Studies from 1947 to 1953, and chairman of The Nature Conservancy from its formation in 1949 to 1953. Perhaps his last public appearance was at the meeting of the British Association at Bristol in September, 1955, when he led a symposium on chalk-grassland by reading a paper on *The Chalk-Grassland Community*. Although this was the last morning of the meeting, the very crowded audience demonstrated the high esteem with which Professor Tansley was held by scientists of all ages.

The writer of this appreciation attended Tansley's lectures on ecology in 1920–1, and when he came back from India in 1947 and found Tansley's book *The British Isles and their Vegetation* was already out of print, Tansley presented him with one of his own last two remaining copies and autographed it for him.

PICEA OMORIKA IN ITS NATURAL HABITAT[1]

By PHILIP WARDLE

SUMMARY

The paper, which is based on a visit to Bosnia in 1954 and on the literature available, describes in detail ten of the principal surviving sites or stations of *Picea omorika* (Pančić) Bolle in the Dinaric Alps and discusses the relationship of the tree to its present restricted environment. The main conclusions are that the spruce, which is a relic in the flora of the Balkan Peninsula, succumbs to competition with other species and is poorly adapted to its present environment but holds its own when competition is absent as on north-facing cliffs or screes or where it has regenerated itself after fire or exploitation.

INTRODUCTION

THE following paper on *Picea omorika*, the Omorika spruce, in its natural habitat is based to a large extent on the literature available, but an essential part of it is the information and experience of the tree gained during a visit to its area in July 1954 when the author spent three weeks as the guest of the Bosnian Forest Service, a visit made thoroughly enjoyable by the unbounded hospitality of the Bosnian people.

The people of Bosnia are mainly peasants whose agriculture is based on the sheep. The right of individual farmers to own land is limited to 37 acres of arable land and 62 acres of forest. The remainder of the forest is controlled by the State Service. However, the only operation in the forests is their exploitation either for firewood in the farmers' woods or for the valuable timber contained in the primeval beech–spruce–silver fir forests. The most serious barrier to the improvement of agriculture and forestry is the poverty of communications. The only railway in the region is the single track between Sarajevo and Belgrade with a branch line to Foča; there are few roads fit for mechanized transport and many villages are served only by foot and bridle paths. Thus much of the forest in which the Omorika occurs has rarely, if ever, been extensively exploited.

The object of the paper is to assess the relationship existing between *P. omorika* and the environment of its natural stations. This is done on the basis of the geological history, recent history, and present distribution of the species, and an examination of the environment and the status, behaviour, and growth of the species.

The specific names used for coniferous species are those given by Dallimore and Jackson in their *Handbook of Coniferae* (2), and for broad-leaved species and shrubs by Makins in his *Identification of Trees and Shrubs* (7). When a species is not included in these works, the name given by the authority drawn on is accepted; specific names have been decapitalized. The spelling of place names is, as far as possible, that used in Yugoslavia.

[1] Based on a thesis prepared as part of the requirements for the degree of B.Sc. with honours in Forestry, University of Aberdeen.

THE PAST DISTRIBUTION OF *PICEA OMORIKA*

At present *Picea omorika* is limited in its natural distribution to a small area in central Yugoslavia (Fig. 1). There is geological evidence, however, that in past eras this species had a wider and more northerly distribution. The comparative morphology of the genus *Picea* also throws some light on this question.

The geological evidence

The fossil record. Fossil material, ascribed to *P. omorika* or its direct ancestors, has been found throughout central Europe. The following records are, except one, listed by Tregubov (11). Fossil remains were found by Conwentz (1890) in Oligocene amber deposits on the Baltic, described under the name of *P. engleri*; by Lokowitz near Mulhouse in Alsace in Middle Oligocene beds (3); by Weber (1908) in Lower Oligocene deposits at Königsberg in East Prussia, and (1904) in Quaternary diluvium near Luneberg, the latter classified with an allied species *P. omorikoides*; and by Wettstein (1892) in interglacial breccia near Innsbruck. Further records from pollen analyses are as follows: in late interglacial deposits in the East Tyrol (Firbas, 1927); in deposits of the last interglacial at Sisak on the Sava in Croatia; in recent peat near Durmitor in Montenegro; and in recent peat on a crystalline schist near Vlasina in central Serbia (Cernjavski, 1934, 1935).

This evidence demonstrates the occurrence of *P. omorika* or its immediate ancestors, at one time or another, throughout central Europe since early Tertiary times.

The geological history. During the Quaternary Glaciation the area of *P. omorika*, which is shown to have been extensive, at least in central Europe, was broken up. The spruce was forced to take refuge in the Balkan Peninsula. The Balkans are believed to have formed one of the three principal regions of refuge for the European flora during the Ice Age (13). Together with other species, whose distribution had previously been farther north, or in the mountains, the Omorika survived in the valleys (11).

At the end of the last glaciation the Omorika failed to reassert itself, probably because of natural barriers to its spread; the species whose previous distribution was farther north migrated to the north or into the mountains (13). Thus, supposing the Omorika to have survived only in the deep valleys of the central massif of the Dinaric Alps, its immediate movement across the northern plains of Yugoslavia at the end of the Ice Age would have been prevented by a mountain barrier. As conditions improved the spruce may have climbed into the mountains, but before it could overcome the barrier they presented, the climate of the plains may already have so changed that the spruce was no longer able to spread across them. Thus, the present limited distribution of *P. omorika* is not necessarily the result of its inherent nature, but may be due rather to geological change and glacial catastrophe.

Taxonomy

Affinities have been pointed out between *P. omorika* and other members of the genus *Picea* by a number of authorities. These species are given below under the

general characters of the section of the genus to which they belong according to Dallimore and Jackson (2).

1. *Section Eupicea*—leaves quadrangular in section, stomata on all four surfaces. Cone scales thick.

(*a*) *Picea orientalis* by Grisebach and Flous (8, 4).
(*b*) *Picea bicolor* by Purkyne and Willkomm (8).
(*c*) *Picea obovata* by Flous (4).
(*d*) *Picea schrenkiana* by Purkyne and Flous (8, 4).
(*e*) *Picea glehnii* by Wettstein (4).

2. *Section Casicta*—leaves unequally quadrangular, flattened, with wide upper and lower surfaces bearing stomata, the side faces compressed and narrow without stomata. Cone scales thin and flexible.

(*a*) *Picea sitchensis* by Willkomm, Novak, and Wettstein.
(*b*) *Picea jezoensis*, especially var. *hondoensis*, by Wettstein, Willkomm, Purkyne, and Novak (8).

3. *Section Omorika*—

(*a*) *Picea omorika* (Pančić) Bolle.
(*b*) *Picea breweriana* S. Wats.
(*c*) *Picea brachytyla* Pritzel.
(*d*) *Picea spinulosa* Henry.

According to this classification *P. omorika* must be most nearly related to other members of the section *Omorika*. However, the leaf form and arrangement and the shape of the leaf cushions suggest a close affinity to the species listed in the section *Casicta*, especially to *P. jezoensis*. Elwes and Henry (3) in fact include the members of the section *Casicta* and those of the section *Omorika* in one section *Omorika*. Close kinship between *P. omorika* and members of the section *Eupicea* can be dismissed on morphological grounds alone; likewise the suggestion, advanced by Wettstein (1892), that *P. omorika* is a mutant of *P. abies*, is not tenable.

An adequate assessment, however, of the relationships existing between these species must await more detailed study. Suffice it to say that the closest relations of the Omorika spruce are probably in the Himalayas (*P. spinulosa*), East Asia and Japan (*P. brachytyla* and *P. jezoensis*), and in Western North America (*P. breweriana* and possibly *P. sitchensis*); and that at some time in the past the distribution of their common ancestors must have been continuous and therefore very different from the present distribution.

The present status of the spruce

The present climate of the Balkans allows the Omorika to survive in the Dinaric Alps only on certain sites; mainly under north-facing cliffs near the mountain summits, where the microclimate is peculiarly moist and cool. There the species is limited to limstone soils, probably because competition from other species is less intense on such soils and not because of their intrinsic suitability.

THE DISCOVERY AND HISTORY OF *PICEA OMORIKA* IN YUGOSLAVIA

The discovery and present area

'Omorika' and 'Omora' are words common in the folklore and sagas of Bosnia, Serbia, and Montenegro, where they symbolize slenderness (8). Pančić, a Serbian botanist, was aware of the name 'Omorika' as early as 1871 and supposed it to be the name of a particular conifer, a pine, or a spruce (11). Whether a real distinction was made between *Picea omorika* and the common spruce by the peasants who used the name is open to question; they probably meant by 'Omorika' a slender spruce of either species. It is unlikely that they did make a distinction, since today the common spruce, more correctly called 'Smrča' in Serbo-Croat, is colloquially known as 'Omorika' in Bosnia, and *P. omorika* is called the 'Pančićeve omorika' or sometimes 'Muljika' to distinguish it. Pančić actually discovered *P. omorika* on Veliki Stolac in Bosnia in 1875 (5). He published his discovery of the species, which he called *Pinus omorika*, in a note 'Eine Neue Konifere in den (sud)-ostlichen Alpen' in Belgrade in 1876 (1, 8, 11).

Since the discovery of the species, most workers have been concerned to establish what is its natural distribution. In addition to numerous private investigations, an official circular was distributed in about 1880 among members of the Forest Service of Bosnia and Hercegovina to obtain records of the tree's occurrence. There were frequent incorrect reports probably due to two reasons; first, to its name being confounded with the colloquial name for the common spruce, and secondly to the acceptance of a slender habit as diagnostic of the Omorika spruce.

At first, the distribution was supposed to be fairly wide; thus Willkomm (1877) states that the species was to be found in Dalmatia, Serbia, and Hercegovina where they bordered on Bosnia and probably in Montenegro and Albania too. It was reported several times from Drobnjači near Durmitor in Montenegro, but Fukarek searched the area thoroughly in 1935 and was unable to find any trace of the species (11). Turril reported the occurrence of the tree in the Rhodops in 1929 as did Hickel, and also from Bulgaria as late as 1931, but Maly when he checked these reports in 1934 found nothing to confirm them (9, 11). It is now established that the tree is confined to a limited area in the middle of Drina valley in west Serbia and the south-east corner of Bosnia. Maps of its area have been prepared by Plavsić (1936), Piskorić (1938), and Kolarović (1951); that of Fukarek (1950) shows the position of all the known stations, and shows those which were destroyed by fire in 1947 and 1948 (5, 6) (Fig. 1).

The area is in three parts which are centred on Radomislje Planina near Foča, on Viogora Planina near Goražde, and on Višegrad. The centres of Foča and Goražde contain only one stand each, the first of about 12 and the second of 10 acres. Višegrad is the principal centre; north of it there are stations on both sides of the Drina numbering fifty-four in all, fifteen of them, however, were destroyed by fire in 1947 and 1948. The largest station is Veliki Stolac, 80 acres, and the next Gostilja, 20 acres; the smallest have only a few trees, at Rakovac, for example, there are only two.

Exploitation

Willkomm (11) supposed that the area of *Picea omorika* had been reduced by destructive felling. There are the following known examples of such exploitation. An area of about 150 acres in the vicinity of Veliki Stolac was, according to

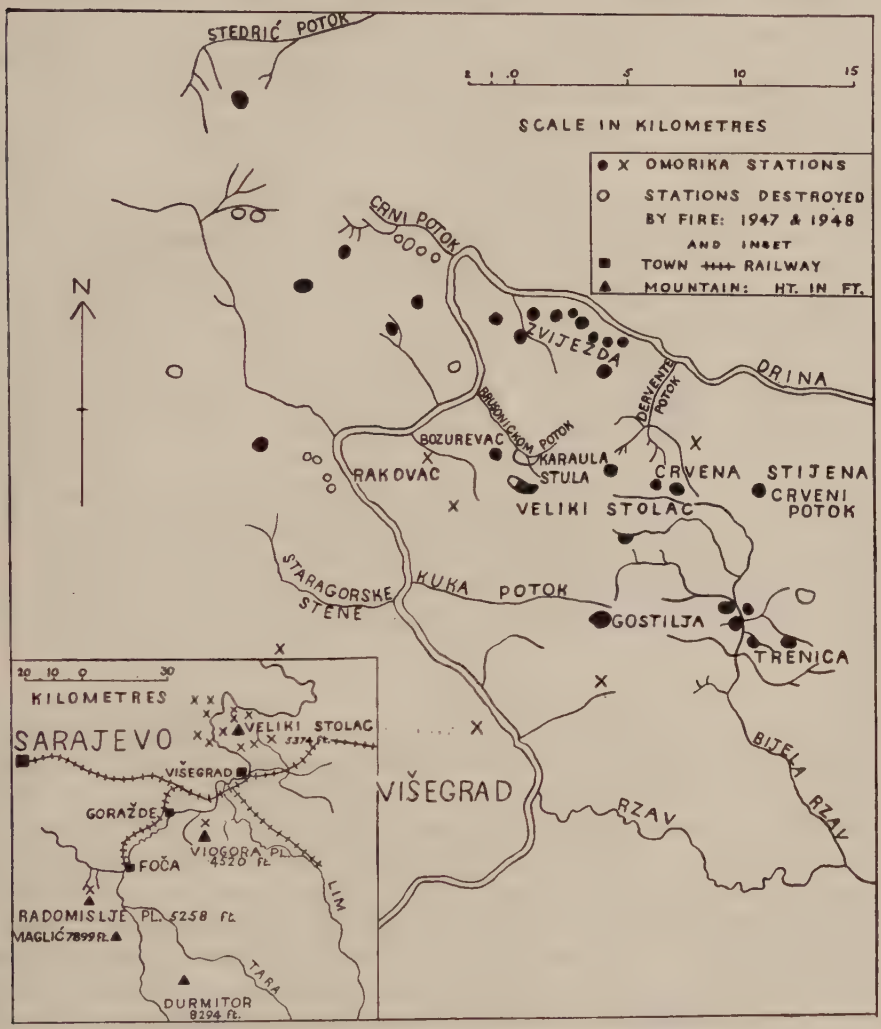

FIG. 1. The stations of *Picea omorika* in the vicinity of Višegrad (after Pavle Fukarek) and, inset, on smaller scale, sketch map to show the position of the area of *P. omorika*.

Karolji (11), clear felled by a timber merchant soon after the occupation of Bosnia by the Austrians in 1883. Though the merchant is said not to have known any difference between the Omorika and common spruce, much of the felling was in the former. After the operation the Omorika regenerated freely, and it may be that the stand at Karaula Stula, burnt down in 1947, once remarkable for its

density and uniformity, was included in this coupe. The few Omorikas remaining at Rakovac in 1936 were felled by a farmer. Rakovac is in a position easily accessible, and it was stated recently that in similarly placed woods owned by farmers in Serbia the tree continued to be felled. A last instance is from Gostilja, where 2 acres were cut by robbers in 1943; the spruce is regenerating there. Because there are so few examples of felling and these mainly of small extent, and since the largest coupes regenerated naturally, it is doubtful if destructive exploitation can have seriously reduced the tree's area, though it may have led to its elimination where only a few specimens were growing on an accessible site.

Fire

A number of stands are believed to have been burnt over in the past. Those at Gostilja and Crvena Stijena among others are characterized by the presence of old emergent pines. The latter, protected by their thick bark, probably survived past fires, while the thin-barked Omorikas with branches persisting to the ground were destroyed and then regenerated. The forest around Rakovac was burnt in about 1850 and recolonized by *Pinus nigra* and the few Omorikas mentioned above. Fires in 1947 and 1948 destroyed fifteen stations, at Karaula Stula, for example, no tree survived, but here and probably in others there is regeneration on the ground.

The extent to which Omorika stands have been completely and irrevocably destroyed by fire in the past is not known. Its response to fire in known cases, and to felling as shown above, shows that it behaves as a pioneer regenerating fairly readily after such catastrophes. Biological and climatic changes have probably been more important causes of any significant reduction in the area of the species.

Protection and preservation

In recent years measures have been taken in Yugoslavia to preserve what is an interesting and valuable relic in the Balkan flora. Before 1934, the Pančić National Park was formed in Bosnia, including three of the largest stations of *Picea omorika*: Veliki Stolac, Karaula Stula, and Gostilja. Felling, grazing, and all operations except collecting seed were excluded from the park (11). It is the objective of the Serbian Forest Service today to create reserves to include all the Omorika stands within the republic. Where a stand at present occurs on a farmer's property, it is proposed to exchange it for land in neighbouring state forest. By 1950, fourteen of the twenty-one stations in Serbia had been declared reserves, and those surrounding Zvijezda formed into a Forest Park (6).

Though the tree is considered to be of little economic value inside Yugoslavia, the seed is known to be valued abroad, and it is thought desirable that this foreign interest should be encouraged (9).

THE NATURE OF THE SURROUNDING COUNTRY

The climate

The climate of the region is described by Tregubov as Continental Montane, and very suitable for forests. It is, however, important to distinguish between the

conditions prevailing among the mountain tops, on north-facing slopes and in the high valleys, to which the following figures refer, and those on south slopes and at lower altitudes. In the former the rainfall is fairly evenly distributed throughout the year and the atmospheric humidity fairly high and uniform. In the latter the humidity is liable to considerable seasonal fluctuation, tending to be low in the summer months, and the distribution of rainfall more and more approaches that characteristic of the Mediterranean region.

The following data are mainly taken from Tregubov (11); Borike is in pasture in the valley of Staragorske Stene, a tributary on the left bank of the Drina, and Han Semeć lies 5 miles to the south (see Fig. 1).

Temperature. The following data are available for 1909.

	Han Semeć 3,870 ft.	Borike 3,215 ft.
Annual maximum	86·0 F.	90·4 F.
Mean maximum temperature hottest month	56·2	57·1
Annual minimum	−29·7	−11·2
Mean minimum temperature coldest month	16·9	20·3
Mean annual temperature	41·2	43·3
Mean 1905–9	39·8	43·7

The following are observations made in two Omorika stands by Wettstein at midday in mid-July, together with the night temperature in one stand.

	1	*2*
In shade	68·8 F.	75·2 F.
In full sunlight	38·3	89·2
Night	60·4	..
Soil at 4 in.	57·5	59·0
Soil at 6 in.	46·8	..
Spring water	..	46·8

The Snijeznika, a shaft about 30 feet deep near the summit of Veliki Stolac, contains snow all the year round and is used by peasants as an ice-house.

Precipitation. The mean annual rainfall for the years 1905–9 was 33·8 inches at Han Semeć and 29·8 inches at Borike. The figure 39 to 47 inches has been given for Veliki Stolac (9). The fall at the former stations is fairly evenly distributed over the year, except for a slight tendency to drought in the early autumn. Snowfall was recorded at Han Semeć on 56 days and at Borike on 42 days per annum over the period 1905–9.

Atmospheric humidity. At Borike the minimum atmospheric humidity was 69 per cent. and the average 76 per cent. in 1909. According to Tregubov (12), the humidity of the atmosphere in Omorika stands at Veliki Stolac and Gostilja 3 feet above the ground never falls below 70 per cent. The average cloud cover over the year at Han Semeć and Borike was 52 per cent. and 63 per cent. respectively and the minimum cover in July was 34 per cent. and 42 per cent. There was fog at Han Semeć on 64 days.

Exposure. The strongest winds in winter are those from the north, and the dominant directions throughout the year north, south, and west, modified by the topography. Winds above force 6 were recorded on 5 days per annum at Han Semeć and on 40 days per annum at Borike over the period 1905 to 1909.

The topography

The Drina rises almost at the Albanian border, south of the highest mountain in the Dinaric Alps, Durmitor, and its highest tributaries are the Lim and the Tara. From Foča to Višegrad the river flows in a deep gorge, the walls rising sheer in places for hundreds of feet. Below Višegrad the valley is wider, but the scenery is typical of limestone country, with steep scarps and steeply rolling hills, dissected by gorges. East of Višegrad the mountains are lower and more gently rolling. The highest peaks are Durmitor (8,294 feet) south of Foča and in Montenegro, and Maglić (7,899 feet) also south of Foča. The highest peaks associated with the Omorika are Veliki Stolac (5,374 feet) north of Višegrad on the right bank of the Drina, Radomislje Planina (5,258 feet) above Foča on the left bank, and Viogora Planina (4,520 feet) below Foča and on the right bank (Fig. 1, inset).

The geology

The rocks are limestone overlying igneous material. Over most of the area the igneous substratum rarely comes to the surface, and the stations of Omorika are on calcareous limestones, mostly rather hard, of the Middle and Upper Triassic and the Upper Cretaceous. One of the most easterly stations is on serpentine. This is the only extant station not on limestone, but the base status of the parent material must be similar to that in the rest of the stations.

The soils

The soil is usually poorly developed, especially on steep slopes and screes where it only consists of accumulations of litter among the boulders. Where it is developed, it is dark brown and rendzina-like but with a raw humus. The moisture and organic matter contents are both high, the upper layers usually acid and the content of mineral nutrients low throughout (9, 11). The formation of raw humus can be ascribed to the poverty of Omorika litter and the cool moist nature of the environment, which favour the activity of fungi rather than bacteria (9). The species has been found by the Forestry Commission to be one of the worse raw humus formers (J. S. Murray, private note). The high moisture content and the low proportions of mineral nutrients are probably mainly due to the high content of organic matter (see Appendix III).

A DESCRIPTION OF TEN STATIONS OF *PICEA OMORIKA* AND THE VEGETATION OF THE SURROUNDING COUNTRY

Ten natural stations of *Picea omorika*, visited in 1954, together with the vegetation of the country which surrounds them, are described below. The lists of tree species given have been augmented where possible by reference to Tregubov (11, 12) and to Fukarek (5). A complete list of species recorded in the Omorika

stations is given in Appendix I (after Fukarek (5)). Notes and a plant list from an ecological study of two of the stations by Tregubov (12) are given in Appendix II.

The vegetation types surrounding each station are described according to aspect and elevation. The vegetation of the station is described in the zone to which it belongs, and its other features are given at the end of the section. To avoid unnecessary repetition, a description of the vegetation of the Stolac Massif is contained in one section, the four stations which fall within its compass being described at the end of that section.

The ten stations are:

1. Radomislje Planina
2. Viogora Planina
3. Veliki Stolac
4. Bozurevac
5. Karaula Stula
6. Rakovac

(The Stolac Massif)

7. Gostilja
8. Trenica
9. Crvena Stijena
10. Crveni Potok

(See Fig. 1).

1. *Radomislje Planina* (5,258 feet)

The mountain Radomislje Planina is about 2 miles south of Jeleć, the nearest village, which in turn is 6 miles west of Foča. Jeleć is situated at the confluence of the Bistrića and the Govza, the latter a tributary of the Drina. The elevation of Jeleć is 2,960 feet and its exact position Lat. 43° 30′ N., Long. 16° 15′ E.

The vegetation surrounding the Omorika station was observed to fall roughly into the following zones according to aspect and elevation; they are not distinct but merge into one another.

The first four divisions were observed on the slopes rising from the Otaša Valley.

The south-east aspect. Below 4,000 feet. The forest is composed mainly of common spruce (*Picea abies*) with the following in mixture: silver fir (*Abies alba*), beech (*Fagus sylvatica*), aspen (*Populus tremula*), and *Quercus* sp. The beech sometimes occurs in groups. The trees are mostly old and many are dead, either fallen or still standing.

From 4,000 to 4,300 feet the mixture is almost exclusively of common spruce and silver fir.

From 4,300 to 5,000 feet the forest becomes rather open on the steep slopes and is composed principally of common spruce, silver fir, and pines, *Pinus nigra*, and *P. silvestris*.

At the summit, over 5,000 feet, the trees occur in groups or singly among the pastures and include silver fir, common spruce, beech, birch (*Betula* sp.), aspen, sycamore (*Acer pseudoplatanus*), Scots pine (*Pinus silvestris*), and black pine (*P. nigra*). Here the pasture is grazed by sheep and cut for hay. The shepherd and his

family live in a tent near the summit during the summer. In places the pasture gives place to a carpet of furze (*Genista radiata*).

The south aspect. Above 3,000 feet the slopes on the opposite side of the Govza from Radomislje Planina are covered by a scrubby forest in which the dominant trees are oaks and beech.

The north aspect. Below 3,000 feet the slopes below the forest on either side of the Govza are agricultural, either pasture or arable land.

From 3,500 to 4,000 feet the greater part of the forest is composed of common spruce, silver fir, and beech either in mixture or forming pure woods. The Omorika is found almost exclusively on the tongues of scree which reach down into the forest from the cliffs. It is the only tree species growing on them and may be found wherever there is a deposit of litter between the boulders. Thus the transition from vegetation on the scree to that on stable soil is often very sharp, the Omorika growing pure on the former and the common spruce on the latter. Sometimes, however, the two species do grow in mixture.

The cliffs 4,000–4,500 feet. The cliffs are extremely steep or sheer and are interrupted only by steep gulleys, the source of the screes below. The tree species growing on ledges or rarely in the gulleys are the Omorikas, black pine, and occasionally beech.

A description of the Omorika station. The elevation of the station on Radomislje Planina is from 2,700 to 4,500 feet, the aspect north to north-westerly. The cliffs 4,100 to 4,500 feet are more or less sheer and the slope below them is very steep, 30 to 40°. The parent material is limestone from the Middle and Upper Triassic. The soil is usually poorly developed, black and rendzina-like. Under common spruce a tough fibrous litter layer of needles is formed. The area covered by the station was estimated by Plavsić, 1937 (5), to be 12 acres with 700 to 800 stems.

Regeneration of *Picea omorika* is scattered; on the slopes above the cliffs it is found with common spruce regeneration and occasionally silver fir and black pine, on the cliffs with black pine, and rarely on the lower screes. Where they are growing in the shade of common spruce on the slopes below the cliffs the young trees are rather spindly and open. Above the cliff there are some dead trees, and in the scree at its foot numbers of fallen stems have accumulated.

2. *Viogora Planina* (4,520 feet)

The mountain is above and to the east of Medurijećje, a village situated, according to the meaning of its name, between two streams, which flow into the Janjina a tributary of the Drina. The village is 6 miles east of Goražde, its altitude 2,000 feet, and its position Lat. 43° 39′ N., Long. 16° 45′ E. The surrounding vegetation falls into the following zones:

The south aspect. Lower slopes below 3,000 feet. The slopes are agricultural, pasture, and arable land, some of the cultivated fields being terraced to prevent erosion.

Upper slopes 3,000 to 4,000 feet. These slopes are covered by scrub forest in which the main species are oak, hornbeam (*Carpinus betulus*), sycamore, and beech. Through much of this scrub the undergrowth has been completely

destroyed by grazing animals and the soils exposed to erosion, leading to the formation of 'terra rossa'.

The summit above 4,000 feet. The pasture, grazed and cut for hay, is interspersed with scrub woodland and poor broadleaved woodland predominantly of beech.

The north aspect. Up to 3,700 feet. The forest is composed of magnificent natural beech, much of it forming pure woods uniform in structure. In places common spruce and silver fir are found in mixture or form pure groups. Hornbeam is fairly common and one specimen of *Tilia platyphyllos*, said to be extremely uncommon in the area, was seen.

The cliffs 3,700 to 4,300 feet. *Picea omorika* is confined to the cliffs and the gulleys which dissect them. There it was seen with beech, sycamore, mountain ash (*Sorbus aucuparia*), and White beam (*S. aria*).

A description of the Omorika station. The Omorika stand is growing between 3,700 and 4,300 feet. Its aspect is northerly and the slope precipitous. The parent material is a triassic limestone, and no stable soil is developed within the station. The estimated area of the station is 10 acres.

There are a large number of dead and dying trees, especially on the slopes above the cliffs. They die from the top of the crown downwards, and there is a heavy growth of lichen on many of the trees.

3 to 6. *The Stolac Massif*

Veliki Stolac (5,374 feet), the highest mountain within the Omorika's area, is above and to the north of Žlijeb, the nearest village, and 10 miles due north of Višegrad. Its position is Lat. 43° 58′ N., Long. 16° 55′ E.

Associated with its northern slopes are three stations of *Picea omorika*; the station Veliki Stolac on the north face, Karaula Stula at the foot of the north face, and Bozurevac on the spur to the west of Veliki Stolac. To the west and near the foot of the last-named spur is Rakovac. The vegetation of the massif falls into the following zones:

The southern aspect. Below 3,000 feet. At this level most of the land is agricultural comprising winter pasture and a few cultivated fields in the neighbourhood of villages.

From 3,000 to 4,500 feet. These slopes are covered by open scrubby woodland, and over wide area the furze, *Genista radiata*. In places the ground vegetation has been completely destroyed, especially around the tracks followed by flocks moving between mountain pastures and the villages. Rills and small gulleys, the result of erosion, were quite common in these places. Tregubov (11) gives a list of the following woody species in this scrub: *Quercus lanuginosa*, *Q. cerris*, *Q. frainetto*, *Fagus sylvatica* (rare), *Fraxinus ornus*, *Acer campestre*, *Ostrya carpinifolia*, *Corylus avellana*, *C. colurna*, *Pyrus communis*, *Ligustrum vulgare*, *Viburnum lantana*, *Crataegus monogyna*, *Cornus mas*, *Clematis vitalba*, and *Juniperus communis*. He mentions also the following species endemic in the Dinaric Alps; *Hieracium plumulosum*, *Melampyrum bosniacum*, *Digitalis laerigata*, and also some calcicolous species.

The summits, above 4,500 feet. Here open forest is interspersed with pastures

and patches of furze. The main tree species are common spruce, silver fir, Scots pine, black pine, and beech. Characteristic of the ground vegetation, according to Tregubov (11), are the mountain and central European species: *Satureja alpina*, *Aconitum variegatus*, *Euphrasia salisburgensis*, and endemics *Senecio rupester* and *Viola elegantula*.

In the pastures, pollarded hawthorns (*Crataegus monogyna*) are used to carry haystacks. The stack is built on top of the pollarded tree, or alternatively within a fence of hawthorn, to protect it from livestock.

The northern aspect. Lower slopes 2,300–3,000 feet. The zone is dominated by black pine. Rakovac is situated towards the upper margin of this zone at 2,900 feet and the tree species recorded there were *Picea omorika*, black pine, common spruce, beech, wild pear (*Pyrus communis*), and Juniper (*Juniperus communis*).

The middle slopes, 3,000 to 3,700 feet. The middle slopes are dominated by a mixture of common spruce and beech which is replaced by pure beech towards the lower limit and by a spruce–silver fir mixture at the upper. Karaula Stula is in this zone; though it is at a lower level the conditions in the deep narrow gorge are similar.

The upper slopes, above 3,700 feet. The spruce-fir forest merges, on steep slopes at Veliki Stolac and Bozurevac, into pure stands of *Picea omorika*. At Bozurevac some of the trees are growing on cliffs. The tree species observed in this zone include the Omorika, common spruce, silver fir, hornbeam, hop hornbeam (*Ostrya carpinifolia*) sycamore, mountain ash, white beam, birch (*Betula verrucosa*), aspen, and the willow (*Salix caprea*). Fukarek also found *Acer monspessulanum*.

A description of the Omorika stations. (3) Veliki Stolac extends from 3,700 to 5,000 feet. The aspect is northerly and the slope is steep, 30 to 50°, with cliffs in some places. The parent material is limestone from the Upper and Middle Triassic, the soil is unstable and rendzina-like. A profile was examined in the soil formation around the roots of an Omorika near the top of the station: the litter layer (depth 2 inches) was composed of twigs and needles, loose or slightly matted; the humus layer (2 inches) was dark brown and moist and was matted or bound by small roots; the humus layer merged into mineral soil (6 inches) which was black to dark brown and loamy, with many roots; the layer (8 inches) immediately above the parent material was dark brown and nutty. Stones were found throughout the profile which here was 18 inches deep.

The area of the station is 80 acres. As was mentioned above, much of this forest is believed to have been felled soon after 1883. The station was damaged in the fires of 1947 and 1948 when about 10,000 stems were destroyed (5). It is one of the more accessible stations and is the main source of seed collected by the Bosnian Forest Service.

(4) Bozurevac is on a western spur of Veliki Stolac. Its elevation is 4,000 feet, the aspect northerly, and the slope extremely steep. The parent material is Triassic limestone and the soil a lithosol on scree. In 1938 there were said to be 30 to 50 trees about 150 years old. In 1950 Fukarek found no regeneration and it appeared to him that the species was being displaced by common spruce and silver fir (5). Some of the trees are dying from the crown.

(5) Karaula Stula is situated at the foot of Veliki Stolac on the south face of the gorge of Brusoničkom Potok, a narrow dark and cool valley (11). The elevation is from 2,800 to 3,000 feet. (It was the lowest station known to Tregubov (11).) The aspect is northerly and the slope extremely steep, 55 to 60° or sheer on the cliffs. The parent material, limestone of the Middle and Upper Triassic, is more or less exposed due to the destruction of the forest litter by fire in 1947. The area of the stand before the fire was 10 acres. The stand was very dense with up to 6,500 stems per acre (11). It was completely destroyed in 1947, and after the fire Fukarek (5) found no regeneration, but the site colonized by elder, *Sambucus racemosa*, *Atropa belladonna*, *Epilobium angustifolium*, and aspen. In 1954 the dominant colonists were aspen, *E. angustifolium*, *Luzula sylvatica*, and *Rubus* (*fruticosus*), with regeneration of *Picea omorika* and common spruce (fifteen Omorikas from 5–8 years old and up to 18 inches high were found in an area of about a quarter of an acre).

(6) Rakovac is an isolated station north-west of Bozurovac on north-facing slopes above Budojski Potok. The station is at 2,600 feet, on a gentle slope facing north-west. The parent material is limestone of the Upper Cretaceous. The soil is a brown forest soil, with a humus layer merging into the mineral soil which is a clay-loam. Only two trees remain and the site is considered too dry and too subject to insolation for *Picea omorika*.

The area is believed to have been burnt over sometime after 1850 and then colonized by black pine and a few Omorikas. The last of the latter was felled in 1936 (the guilty farmer was fined but never made to pay as the result of an amnesty), but their stumps show them to have been from 8 to 10 inches in diameter and one of them had sixty annual rings (5).

Two trees which remain are under the shade of pines and of rather spindly and open form; the larger is 15 feet high, 3 inches in diameter with thirty rings at breast height; the smaller tree is only 3 feet high.

7. *Gostilja* (4,330 feet)

The mountain is 6 miles north-east of Višegrad. The surrounding vegetation falls into the following zones:

The south aspect. 3,000 to 4,000 feet. The slope is very steep with cliffs in places. The vegetation is dominated by scrub of the following species: beech, hazel, hornbeam, hawthorn, and field maple (*Acer campestre*).

The summit, above 4,000 feet. The scrub is scattered among pastures and includes the following species: aspen, hazel, hornbeam, juniper, sycamore, birch, *Quercus* spp. (including *Q. cerris*), white beam, mountain ash, willow, wild pear (11), hawthorn, birch (11), *Rosa alpina*, *R.* sp., *Rubus idaeus*.

The north aspect. Here the vegetation falls into three zones. A strip transect was made through the two upper zones.

Below 3,000 feet. The forest is of black pine, which is tapped for resin.

3,000 to 3,700 feet. This zone consists of broadleaved forest dominated by beech. Included among the other species are: sycamore, hornbeam, hop hornbeam, aspen, elm (*Ulmus montana*?), *Cornus* (*mas*).

The upper slopes, 3,700 to 4,300 feet. Below the foot of the cliffs the forest is mainly of coniferous species with broadleaved species scattered through it. On the cliffs and in the common spruce forest below, there are numbers of emergent black pines. Besides *Picea omorika* the main species in this zone are common spruce, black pine, birch, aspen, sycamore, mountain ash, white beam, and willow.

An area clandestinely felled during the last war has been colonized by aspen, sycamore, mountain ash, *Rubus idaeus*, *Calamagrostis vaira*, and *Luzula sylvatica*. Regeneration of Omorika and common spruce up to 10 years old and 2 feet 6 inches high is frequent.

The transition from this type to the scrub type of the southern aspect at the summit is extremely abrupt. Nowhere do the Omorikas on the north face reach above the cliffs to be exposed to direct sunlight, though they are found immediately below them.

A description of the Omorika station. The station is between 4,000 and 4,300 feet, its aspect north, and its slope precipitous. The parent material is limestone of the Upper Cretaceous and the soil undeveloped or rendzina-like. The area of the station is about 20 acres (11).

The uniformity of the Omorika stand on the slopes and the presence of old emergent pines suggest that the station has been burnt over in the past (11). Further damage was done by fire in 1948 (5). A number of trees are dying from the crown.

8. *Trenica*

The station is situated on the south bank of Smajevi Potok, a tributary of the Bijela Rzav; the nearest village is Durići in the commune of Zaovine and as the crow flies, 7½ miles from Višegrad. Trenica is the first of three stations in Serbia to be described.

The south aspect at 2,600 feet. The south-facing slopes above Smajevi Potok are scree-covered and otherwise bare except for sparse scrub and grasses.

The north aspect at 2,600 feet. The north slopes are forested by black and Scots pines; the Omorikas are concentrated on a small area around a spring (5). Noteworthy among the species listed from the station is *Parnassia palustris* indicating the moistness of the site.

A description of the Omorika station. The station, at 2,600 feet, has a northerly aspect and a slope of 30° (Kolarović says 35 to 40° (5)). The parent material is serpentine and in this respect the station is unique. The soil is rendzina-like, but with a raw humus. A profile examined in the stand showed the following layers: a litter layer (2 inches) composed of moss, twigs, and needles forming a mat bound by roots of *Erica carnea*; a black humus layer (½ inch); a nutty dark brown mineral soil (the transition from the humus layer being abrupt); a loose dark brown loamy layer with medium stones and a loamy sand lighter brown. The depth of the mineral soil horizons was greater than 2 feet. The soil was moist and pieces of decomposing serpentine were found throughout the profile. The ground vegetation which is sparse includes *Erica carnea*, *Vaccinium myrtillus*, and *Hylocomium splendens* as its principal species.

Fukarek states that there are now thirty-seven trees and that 150 dead ones were felled in 1948 (5). Few of the trees that remain have the characteristic imbricate habit of Omorika, most of them being irregular and spreading and some have been deformed by contact with the neighbouring pines (5).

9. *Crvena Stijena* (3,900 feet)

The mountain is in Serbia, about 10 miles north-east of Višegrad and 5 miles due east of Veliki Stolac. The nearest villages are Jokići and Kremići at the foot of its north slopes. The range of hills, of which Crvena Stijena is one, forms the watershed between Bijela Rzav, an eventual tributary of the Drina which flows south, and Dervente Potok, which flows north into the Drina.

The vegetation is described from three aspects.

The east aspect. Below 3,000 feet. The forest is predominantly of beech, many of the large trees having dead crowns.

The south aspect. Below 3,000 feet. The land is devoted to pasture.

3,000 feet to the summit. The pasture is interspersed with woodland of the following species: black pine, beech, hornbeam, white beam, ash (*Fraxinus ornus*), and alders (*Alnus glutinosa* and *A. incana*).

The north aspect. Below 3,000 feet. The land is devoted to pasture, arable farming, and orchards.

From 3,000 feet to the summit, the pasture merges into forest. *Picea omorika* is scattered throughout, but is most frequent near the cliffs at the top. It occurs singly or in pure groups. Old emergent pines are most conspicuous in this forest.

The following tree species were observed on a strip transect made from the foot of the cliffs down through the forest: *Picea omorika*, common spruce, silver fir, black pine, birch, beech, hornbeam, sycamore, hop hornbeam, ash (*Fraxinus ornus*), and alder (*Alnus glutinosa*),[1] the proportion of broadleaved species increasing towards the bottom of the forest.

A description of the Omorika station. The elevation of the station ranges from 3,000 to 3,900 feet, the aspect is northerly, and the slope steep (greater than 30°), the cliffs being sheer. The parent material is limestone of the Middle and Upper Cretaceous and the soil rendzina-like. No estimate is available of the exact extent of the station. The forest has probably been burnt over in the past.

10. *Crveni Potok* (3,300 feet)

The station is on the main plateau of Tara Planina very close to Mitrovac (3,500 feet). It is about 13 miles from Višegrad and in Serbia.

The surrounding forests are mixed irregular forests in which the principal species are silver fir, beech, and common spruce. In places all size classes of silver fir are found in intimate mixture, giving an impression of true selection forest. Though large-sized beech are present, middle sizes and regeneration of the species are almost completely absent. The forest is open to grazing animals and apparently the beech regeneration is grazed while that of silver fir is ignored, and only stunted specimens of the former survive.

[1] The alder, *Alnus glutinosa*, has not been recorded by any other authority from the station of *Picea omorika*.

The *Picea omorika* stand is in a shallow marshy depression, the ground waterlogged in winter, and partly protected from grazing. Species found together with the Omorika were common spruce, silver fir, and alder, while *Vaccinium myrtillus* is prominent in the ground vegetation.

The station comprises about forty old trees (5) scattered through the above mixture, the stand being rather open. No regeneration of *Picea omorika* has been found. Most characteristic of the trees on this site is their growth on mounds, like ant-hills, which are colonized by *Vaccinium* and mosses. The stems are buttressed and the root system appears to be more or less superficial and plate-like (5). Many of the trees are dying from the crown.

General features of the surrounding vegetation

On the basis of the above observations, the vegetation of the country surrounding the Omorika stations just described is shown to fall into the following zones, the positions of which have been marked tentatively on the map of Stolac and Gostilja (Fig. 2). They are not sharply defined but merge, and their actual position may be considerably altered by the configuration. Tregubov (11) lists six zones for the south aspect, but although the species he lists were found they did not appear sufficiently characteristic of any one position to define a zone, nor were they limited to one altitudinal position. The general zones are more satisfactory since they are less liable to become confused due to slight variations in the topography.

I. *Agricultural land*: below 3,000 feet. In this zone are farms and villages surrounded by arable land, orchards, and winter pasture. Where the land is too poor for agriculture, there are forests of black pine and oak scrub. Where the terrain is irregular, and on the north slopes, the upper limit of the zone may be less than 3,000 feet. These are mainly on the south aspect.

II. *Scrub*: 3,000 to 4,000 or 4,500 feet. The south slopes at this height are hot and dry in summer and are covered by poor scrub woodland. The ground under the scrub is sometimes denuded of vegetation by grazing animals, in other places the scrub gives way to open slopes with *Genista radiata*. Examples listing the main species composing the scrub are given from Viogora, Stolac, and Gostilja.

III. *Woodland and pasture*: above 4,000 or 4,500 feet. At this height the conditions of temperature and moisture are more favourable for tree growth. Pasture is interspersed with rather open woodland including both broadleaved and coniferous species. This type is mainly on the north aspect.

IV. *The pine zone*: below 2,700 feet. Continuous black pine forest is found at this level on the north aspect, and reaching slightly higher on the east and west aspects.

V. *Mixed broadleaved zone*: 2,700 to 3,000 or 3,500 feet. Mixed broadleaved woodland, composed predominantly of beech, is found at this level. On aspects other than north it occurs up to 4,000 feet, but on the north slopes it gives place to spruce-fir forest at 3,500 feet or below. The beech forest is very fine, often more or less uniform in structure, maintaining itself through regeneration in groups.

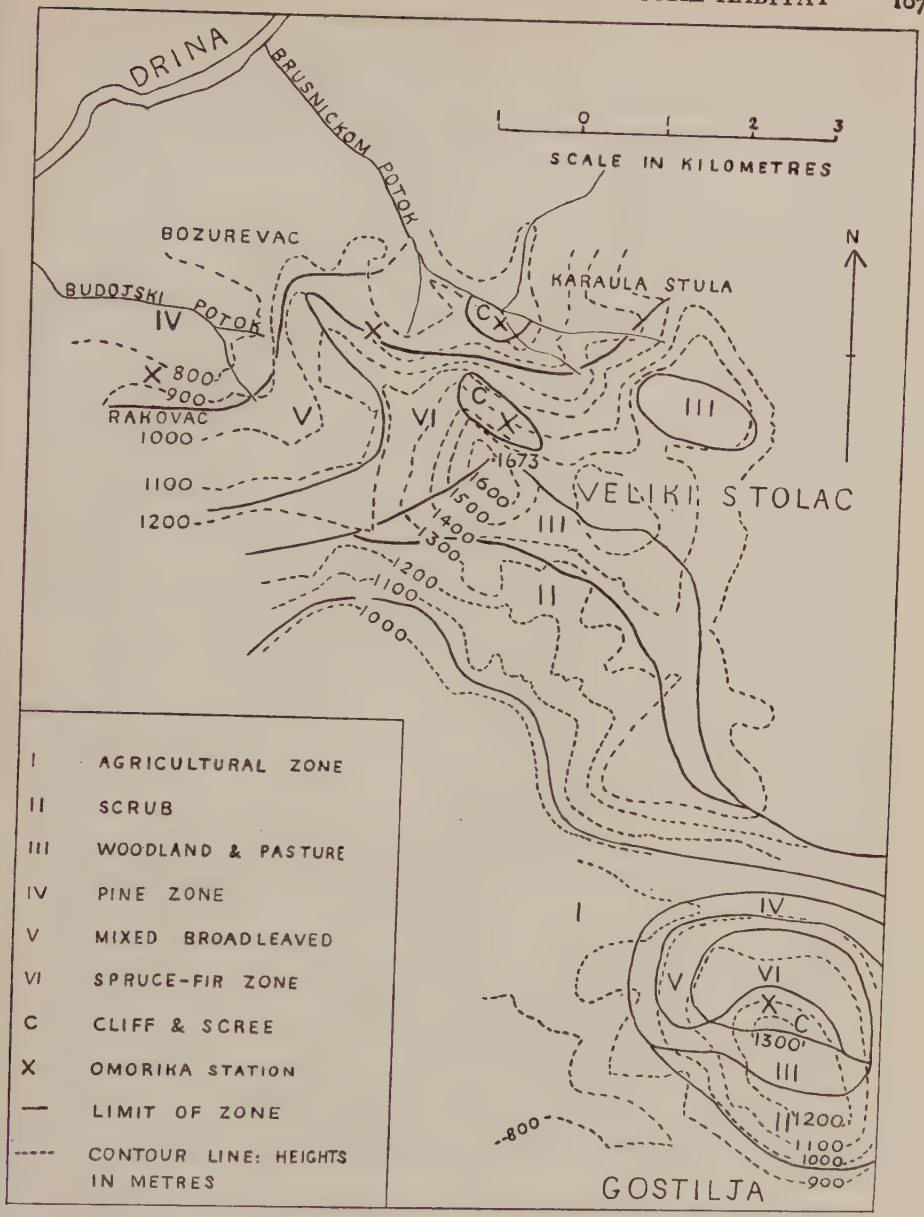

FIG. 2. The vegetation of the Stolac Massif and Gostilja.

VI. *Spruce–fir forest*: 3,000 to 4,500 feet. The principal species is common spruce with silver fir and beech in mixtures. Omorika spruce occurs in this zone but usually on the scree or steep slopes at its upper limit below the cliffs.

VII. *The cliffs and screes*: over 4,500 feet. On these extremely steep slopes the only species found are *Picea omorika*, the black pine, and occasional beech. On the scree the Omorika is almost the only species.

There is evidence to suggest that the 'black pine' at this altitude is *Pinus leucodermis*, the Bosnian pine. The sites are similar to those from which the species has been described (2); also photographs of Tregubov's (11), and Plate VII shows the pine to have light coloured bark.

General features of the Omorika stations

The Omorika stations are confined to the zones of the north aspect and occur principally in the last three; they are of the following kinds:

A. The cliff stations with *Pinus leucodermis* are mostly above 4,000 feet, but there are a number of exceptions such as Karaula Stula which is at about 2,800 feet. The lowest recorded Omorikas are in a cliff station in the Zvijezda Massif at 1,300 feet (6). The forest in these stations is of necessity open and never receives direct sunlight. Examples of this type are found at Radomislje Planina, Viogora, Karaula Stula, and Gostilja (Plate VII).

B. Stations in the upper spruce–fir zone are either on scree slopes, where the associated species offer no competition, or are uniform stands following catastrophes, such as fire and exploitation. In the latter, the Omorika stand tends to be replaced by common spruce and silver fir in the absence of new catastrophe allowing its regeneration. Stands of this type are found at Radomislje Planina, Veliki Stolac, Bozurevac, Gostilja, and Crvena Stijena (Plate VIII).

C. The third type includes the low-lying stands which exist only as the result of catastrophe and are on the margin of the species' tolerance. They are often accessible. The species is most short-lived in these sites, which show no peculiar features favouring the species apart from the original catastrophe which allowed its regeneration. An example is Rakovac.

D. Finally there are those stations which depend for their survival on a surfeit of ground water although other conditions are beyond the species' tolerance. Such stations are Trenica and Crveni Potok.

Common to all the stations is a north aspect, with in many instances complete protection from direct sunlight, which makes the site cooler and moister than the surrounding country. Secondly, in all cases the spruce is freed from competition from other species, either permanently, as on the cliffs and scree, or at the time of its regeneration which is almost invariably found following catastrophe, such as fire or exploitation. Even so, in dry years the spruce suffers from drought and there have been heavy losses in a number of stations. Losses from all causes are most likely to occur in the lower stations such as Rakovac and Trenica and Crvena Stijena, which are not particularly favoured by their configuration.

GROWTH AND DIMENSIONS OF *PICEA OMORIKA*

In seven of the natural stations of *Picea omorika*, measurements of girth at breast height, height, and diameter increment were made to obtain some estimate of the tree's growth in Yugoslavia. The distribution of size classes was determined in sample areas in three stations.

Heights were either measured using a Brandis's Hypsometer or, where this was

Omorika on the cliff at Radomislje Planina with *Pinus leucodermis*

PLATE VII

A slope in the spruce-fir zone at Gostilja

PLATE VIII

made impossible by the nature of the terrain, estimated. The diameter increment was found using a No. 1 Pressler's borer to determine the number of annual rings to the last inch of diameter. Sampling was on the whole subjective. Sample areas were examined in the stations at Gostilja, Crvena Stijena, and Trenica. At the first two the samples are based on strip enumerations carried out on screes, where it was possible to get down the slope. At the third, a tenth acre sample plot was measured where the trees were most concentrated, the remainder being more scattered through the wood. Within the sample areas the girths of all the trees were measured, together with the height and diameter increment of sample trees selected to cover the range of girths. Similar measurements were made on individual trees in the remaining four stations, those being measured that could be reached.

The sample tree data are given in Table I. The values given for basal area increment per cent. were calculated according to Schneider's formula, thus:

$$\text{per tree} \quad . \quad . \quad \frac{400}{nD}$$

$$\text{per station} \quad . \quad . \quad \sum \frac{400\,D}{n} \Big/ \sum D^2 \text{ (Borggreve's modification)}$$

(n is the number of rings to the last inch of diameter and D the diameter). No correction was made for bark thickness and the diameter obtained was from over-bark girth. The distribution of size classes within the sample areas is shown in Table II.

From Table I it can be seen that the main trend is for the percentage increment to diminish as the girth increases, which is of course to be expected. Low values for Crveni Potok can be attributed in part to drying out of the bore spills before the rings were counted. Although from the available data the growth at Crvena Stijena does appear to be consistently higher than in other stations, no significant difference can be established between the growth at different stations. In general it can be said that the increment is very small, especially when the low density of the stands, shown for three of the stations, is taken into account. This is borne out by Tregubov (11), who obtained similarly low increment values.

The tables show, in addition to the generally slow growth and poor stocking, a dearth of large sizes. The largest tree recorded was 59 inches in girth with a measured height 72 feet, and the tallest, 53 inches in girth with an estimated height of 96 feet. The largest tree recorded by Tregubov (11) had a girth 66 inches and a height of 164 feet. He gives figures showing the density of stands at Karaula Stula, where he recorded 6,500 trees per acre with mean height 43 feet, mean girth 10·3 inches, and a volume of 4,500 cubic feet (Hoppus) per acre, and at Veliki Stolac where he found 340 trees per acre, 130 of them Omorikas, with a total basal area of 120·8 square feet (Hoppus) per acre, and a total volume of 3,700 cubic feet (Hoppus) per acre. Generally, except where the stand follows fire or clear felling, stocking is not dense, the Omorikas being scattered through rather open mixed forest, or on cliffs and scree slopes.

TABLE I. *The girth, height, and increment of sample trees from seven stations*

Station	*Girth in.*	*Height ft.*	*Rings per last inch n*	*Diameter inches D*	$\frac{400D}{n}$	D^2	$\frac{400}{nD}$	*Remarks.*
Radomislje Planina	53	75	30	16·9	225	285	0·790	Girth at 6 ft. ht. estimated
	27	60	28	8·6	123	74	1·66	gbh. Ht.-e.
	59	73	26	18·8	290	354	0·82	Ht.-measured
	53	96	..	16·9	..	..	..	Ht.-estimated
	49	90	40	15·6	156	243	0·70	Ht.-estimated
	29	40	18	9·2	204	85	2·42	Ht.-estimated
	16	30	12	5·1	170	26	6·55	Ht.-estimated
	8	15	..	..	..	..	..	Ht.-estimated
			Periodic mean annual increment = 1·0%					
Veliki Stolac	31	..	35	9·9	113	980	1·15	..
	19	..	35	6·1	98	37	1·87	2 stems on one stump
Bozurevac	40	67	16	12·8	320	164	1·95	Ht.-estimated
Gostilja	31	81	26	9·9	152	98	1·55	All heights measured
	25	68	21	8·0	152	64	2·38	
	22	53	28	7·0	100	49	2·04	
	16	20	..	5·4	..	..	..	
	14	54	32	4·5	56	20	2·78	
			Periodic mean annual increment = 2·0%					
Trenica	25	46	..	8·0	..	..	..	All heights measured
	21	60	28	6·7	96	45	2·14	
	19	48	25	6·1	98	37	2·62	
	16	46	26	5·1	78	26	3·02	
			Periodic mean annual increment = 2·52%					
Crvena Stijena	46	64	16	14·6	365	213	1·71	Outside strip
	41	76	18	13·0	290	169	1·71	All heights measured
	34	76	18	10·8	240	116	2·06	
	19	18	18	6·1	136	37	3·64	
	17	49	15	5·4	144	29	4·95	
	15	20	13	5·8	148	23	6·40	
			Periodic mean annual increment = 2·25%					
Crveni Potok	36	77	29	11·5	159	132	1·20	All heights measured
	32	71	43	10·5	86	110	0·89	
	30	50	47	9·5	81	90	0·90	
			Periodic mean annual increment = 0·98%					

TABLE II. *Distribution of size classes in sample areas*

Girth Class (in.)	Regeneration	15	18	21	24	27	30	33	36	39	42	45	*Total measured* No.	*Total measured* B.A. ft.² H.
Basal area ft.² H.		0·124	0·179	0·244	0·318	0·403	0·497	0·602	0·716	0·841	0·975	1·119		
Gostilja—0·16 acres														
Species—*Picea omorika*	..	2	..	..	1	1	3	..	..	..	1	..	8	3·435
Others	..	CP	..	NS	..	CP	..	..	..	..	CP	..	4	1·746
													12	5·181
Total	..	..	..	..	..	..	..	..	..	..	..	..	75	32·6
Per acre	..	..	..	..	..	..	..	..	..	..	..	..		
Trenica—0·10 acres														
Species—*Picea omorika*	..	3	4	5	2	..	..	..	..	..	..	..	14	2·932
Pinus silvestris	1	2	3	3	4	1	2	2	..	..	..	..	17	5·390
Others	NS	NS	..	2 CP	..	..	..	CP	..	..	..	..	4	1·214
													35	9·536
Total	2	..	..	..	..	..	..	..	..	..	..	..	350	95·0
Per acre	..	..	..	..	..	..	..	..	..	..	..	..		
I. *Crvena Stijena*—0·16 acres														
Species—*Picea omorika*	16	2	6	1	..	..	..	..	..	..	..	..	9	1·566
Pinus nigra	4	1	..	2	2	2	5	1	..	..	1	1	15	7·235
Others	26 NS	..	..	2 NS	2 NS	..	NS	..	..	..	..	..	5	1·622
	4 SF	Aspen, Beech, Sycamore, and *Ostrya*							..	..	..	..	..	..
													29	10·423
Total	50	..	..	..	..	..	..	..	..	..	..	..	180	65·0
Per acre	..	..	..	..	..	..	..	..	..	..	..	..		
II.—0·16 acres														
Species—*Picea omorika*	49	1	1	..	..	..	..	..	1	..	1	..	4	1·746
Pinus nigra	4	1	4	4	2	6	2	..	1	1	1	2	24	10·634
Others	40 NS	..	..	..	..	..	..	..	..	..	..	..	..	..
	3 SF	..	..	..	..	..	..	..	..	..	..	..	..	..
													28	12·380
Total	96	..	..	..	..	..	..	..	..	..	..	..	175	77·0
Per acre	..	..	..	..	..	..	..	..	..	..	..	..		
III.—0·13 acres														
Species—*Picea omorika*	3	..	..	1	1	..	..	..	..	..	..	..	2	0·562
Pinus nigra	..	3	3	1	2	..	..	..	1	..	..	..	10	2·505
Others	6 NS	..	4 NS	..	..	..	..	..	..	..	..	..	4	0·716
	4 SF	Alder and Sycamore				..	..	..	..	..	..	..	..	..
													16	3·783
Total	13	..	..	..	..	..	..	..	..	..	..	..	123	29
Per acre	..	..	..	..	..	..	..	..	..	..	..	..		

CP = *Pinus nigra*; SF = *Abies alba*; NS = *Picea abies*

CONCLUSIONS

It is clear that *Picea omorika* is a relic in the flora of the Balkan Peninsula. Its restricted distribution, slow growth, and intolerance of competition from other species show it to be poorly adapted to its present environment. The nature of the sites on which the Omorika is found, north slopes near the summits of mountains and other places peculiar for their comparative moistness, and the fact that the death of numbers of trees in certain stations is due to drought, indicate that the main factor limiting its growth is the water available. Certain features of the tree's behaviour in its natural stations can be put down to the environment and may be expected to change when the species is introduced to more favourable conditions; it has, for example, succeeded on a wide range of sites in Great Britain. On the other hand, some of its characteristics are inherent and of direct importance when considering the tree's growth outside the Balkans. Among them is its strong tendency towards the formation of raw humus. This suggests that the tree's nutrient uptake, and thus the demand it makes on the site, is small and perhaps explains the Omorika's success on such poor sites as peat moorlands in Britain.

ACKNOWLEDGEMENTS

In the first place, I wish to thank Professor H. M. Steven for his advice and encouragement throughout the preparation of this paper. In Sarajevo I had the good fortune to meet Professor Pavle Fukarek who gave me the benefit of his particular knowledge of the Omorika's area and introduced me to the Director of the Bosnian Forest Service; the warm hospitality of the forest community of Bosnia made my visit a very happy one. Last, a number of people have helped in compiling the paper since I returned, I would mention particularly Mr. and Mrs. Binns who read and typed the text before publication. I would thank them all most kindly.

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APPENDIX I

The Piceetum Omoricae after Fukarek (5)

Trees

Picea omorika
P. abies
Abies alba
Sorbus aucuparia
Betula verrucosa
Pinus sylvestris
Fagus sylvatica
Acer pseudoplatanus
Populus tremula
Salix caprea
Pinus nigra
Ostrya carpinifolia
Fraxinus ornus
Sorbus aria
S. torminalis
Quercus petraea
Tilia cordata
Pyrus piraster
Carpinus betulus
Prunus avium
Fraxinus excelsior
Ulmus montana
*Alnus glutinosa**

Shrubs

Lonicera xylosteum
L. alpigena
Daphne mezereum
Rhamnus fallax
Rubus hirtus
Rosa pendulina
Spirea ulmifolia
Cytisus nigricans
Juniperus communis
Rubus idaeus
Corylus avellana
Daphne blagayana
Spirea cana
Cotoneaster integerrima
Amelanchier ovalis
Rhus cotinus
Sambucus racemosa
*Cornus mas**

Ground Flora

1. *Spruce Phase*

Vaccinium myrtillus
V. vitis-idaea
Spruce Phase (cont.)
Luzula sylvatica
Hieracium transsylvanicum
Pyrola secunda
Laserpitium marginatum
Doronicum columnae
Goodyera repens
Orchis maculata
Melampyrum hoermanianum

2. *Beech Phase*

Lathyrus vernus
Euphorbia amygdaloides
Asperula odorata
Anemone hepatica
Asarum europaeum
Sanicula europaea
Epimedium alpinum
Lilium martagon
Lactuca muralis
Actea spincata
Salvia glutinosa
Pulmonaria officinalis
Campanula persicifolia
Senecio umbrosis
S. fuchsii
Oxalis acetosella
Saxifraga rotundifolia
Gentiana asclepiadea
Veronica latifolia
Geranium robertianum

3. *Associated Species*

Erica carnea
Euraiathus graminifolius
Heliosperma sp.
Calamagrostis varia.
Geranium macrorbisum
Solidago virga-aurea
Aremonia agrimonioides
Valeriana montana
Epilobium montanum
Cersium erisithales
Galium schultesii
Prenanthe purpurea
Brachypodium sylvaticum
Fragaria vesca
Festuca montana
Veronica chamaedris
Associated Sp. (cont.)
Galium lucidum
Knauta sarajevoensis
Libanotis montana
L. media
Origanum vulgare
Circea lutetiana
Silene quadridentata
Saxifraga crustata
Senecio rupestris
Campanula rotundifolia
C. patula
Digitalis ambigua
Parnassia palustris
Daucus carota
Gentiana cruciata
Epilobium angustifolium
Succisa pratensis
Arabis procurens
Aruncus sylvestris
Cicerbita pancici
Dianthus kitaibelii
Mebringia muscosa
Centaurea triumffetti
Chrysanthemum corymbosum
Astragulus glycyphylos

Ferns

Phegopteris robertiana
Nephrodium felismas
Polypodium vulgare
Asplenium viride
A. trichomanes
Nephrodium spinulosum
Dryopteris aculeata
Pteridium aquilina
Equisetum hyemale

Mosses and Liverworts

Hylocomium splendens
Rhytidiadelphus triqueta
Ctenidium molluscum
Eurhynchium striatum
Dicranum scoparium
Tortella tortuosa
Plagiochila asplenioides
Stereodon cupressiforme
Marchantia polymorpha
Radula complanata

* These Species added by the author.

APPENDIX II

A study of Five Quadrants at Veliki Stolac and Gostilja

Notes taken from Tregubov (12)

A general description of the quadrants

1. *Gostilja*—area 100 m.²

Picea omorika . .	15 trees dbh 12–25 cm.
Pinus nigra . .	6 trees dbh 3–10 cm.
Picea abies . .	4 trees dbh 4–12 cm.

(Other species as in Table.)

The small openings between the trees are occupied by tufts of *Erica carnea*.

2. *Gostilja*—near the summit and containing elements from the neighbouring beech woods.

3. *Stolac*—in the middle of an Omorika stand. The groups of *Picea omorika* are interspersed by small clearings, the margins dominated by *Erica carnea* while the centres contain *Calamagrostis* and *Luzula*. *Hieracium transsylvanicum* is localized under the trees. Regeneration of *Picea omorika* and common spruce is found next to the clumps of Erica.

4. *Stolac*—a dense and uniform stand.

5. *Gostilja*—resembling 4. On 100 m.²

Picea omorika . .	22 trees dbh 11–19 cm.
Picea omorika . .	5 trees dbh 5–8 cm.
Betula verrucosa .	2 trees dbh 10–19 cm.

Gostilja—on another site adjoining (5) in a clearing of about 80 m.² among groups of *Picea omorika*, the herbaceous cover (90%) is composed thus:—

Calamagrostis varia . . .	4·4	*Dryopteris robertiana* . .	1·2
Galium schultesii . . .	3·3	*Lathyrus vernus* . . .	1·2
Luzula sylvatica . . .	2·2	*Gentiana asclepiadea* . . .	1·2
Sorbus aucuparia . . .	1·2	*Doronicum columnae* . . .	1·1
Lonicera xylosteum . . .	1·1	*Hieracium transsylvanicum* . .	1·1
Salix caprea	1·0		

Conclusions

From these observations, and since *Picea omorika* increases in groups, between which the vegetation is very different, Tregubov concludes that the forest has not in fact acquired a state of equilibrium, the present vegetation representing only an evolutionary stage. This, he says, is borne out by the *P. omorika* woods themselves, which are young and contain trees of small stature.

The ecological notation follows Braun-Blanquet.

First number denotes abundance

5. Surface cover more than 75 per cent.
4. Surface cover more than 50–75 per cent.
3. Surface cover more than 25–50 per cent.
2. Surface cover more than 25 per cent.
1. Cover feeble but plant abundant.

Second number denotes sociability

5. Crowded and continuous.
4. In large groups.
3. In large tufts or clumps.
2. Small clumps.
1. Plants isolated.

The vegetation of the quadrants

Quadrants	*1*	*2*	*3*	*4*	*5*
Altitude metres	1·130	1·260	1·270	1·170	1·180
Aspect	NNE.	N.	ENE.	NE.	NNE.
Slope in degrees	31	30	40	36	34
Area examined m.²	100	400	600	200	100
Tree cover					
Cover per cent.	50	55	55	80	80
Mean dbh. cm.	20	14	20	18	14
Mean height m.	23	12	20	19	17
Picea omorika	3·4	4·3	4·4	5·5	5·5
Picea abies	1·1	1	1·1	1·1	..
Pinus nigra	1·1	1·1	1	1	..
Betula verrucosa	1·1	1	1	..	1·1
Salix caprea	1	1·1	1	..	1
Populus tremula	1	1·2	..	1	..
Fagus sylvatica	1	1	1	..	..
Pinus sylvestris	..	..	1	..	..
Herbaceous cover per cent.	90	80	60	30	20
Species of the order Vaccinio-Piceetalia					
Vaccinium myrtillus	3·4	1	4·4	2·4	2·4
Rosa pendulina	2·2	2·2	1·1	1·1	1·2
Hieracium transsylvanicum	2·2	1·2	2·2	1·1	1
Luzula sylvatica	1·1	2·2	2·2	1·1	1
Sorbus aucuparia (reg.)	1	1·1	..	..	1
Doronicum columnae	..	1·2	..	1·1	1
Peltigera aphtosa	..	..	1·4	1·4	2·4
Pyrola secunda	1	..	1	1	..
Goodyera repens	..	..	1	1	..
Calcicolous species					
Erica carnea	4·4	1·4	3·4	1	1
Calamagristis varia	3·4	3·4	3·4	2·4	1
Valeriana montana	1·2	2·2	1·1	1·1	1
Gentiana asclepiadea	1·1	2·2	1·1	1·1	1
Euphorbia amygdaloides	1	2·1	1·1	2·1	1
Lathyrus vernus	..	2·1	1·1	1·1	1
Cirsium erisithales	1·2	2·1	..	..	..
Anemone hepatica	2·3	2·3	..	..	..
Associated species					
Veronica chamaedris	1·2	1·1	1·1	1·1	..
Galium schultesii	1·2	1·3	1·1	..	..
Libanotis montana	..	1	1·1	1·2	..
Spiraea ulmifolia	1	..	..	1·1	1
Succisa pratensis	1	..	1	1	..
Laserpitium marginatum	1·2	1·1	1	..	..
Daphne mezereum	1	1·1	1	..	..
Moss cover per cent.	80	80	60	20	60
Hylocomium splendens	1·5	4·5	4·5	1·4	2·2
Rhytidiadelphous triquetea	4·5	3·5	1·5	1·4	2·5
Ctenidium molluscum	1·5	1·5	1·5	1	1
Eurhynchium striatum	1·5	1·3	1	1	1
Dicranum scoparium	1	1	1	1	1

APPENDIX III

The Soil under Picea Omorika *at Tara*

Notes from Poledića and Stankević (9)

The forest is mixed; Omorika, common spruce, silver fir, beech, hornbeam; the Omorika being the principal species.

Character of the soil

The soil has an average depth of 40 cm. It is dark brown, fresh, porous, with no pronounced structure, crumbly, friable, stony; the humus changes sharply into mineral soil. It is a young soil and a rendzina.

Moisture content—9·51–16·61 per cent.
Hygroscopicity—20·92–36·54 (Moisture content × 2·2)

Mechanical analysis

Depth cm.	*Coarse sand* % 0·2 mm.	*Fine sand* % 0·2–0·02 mm.	*Clay* % 0·02–0·002 mm.	*Silt* 0·002	*Total sand* %	*Total silt and clay* %
0–10	52·00	28·00	13·10	6·90	80·00	20·00
11–25	57·00	28·10	9·50	5·40	85·10	14·90
26–41	40·00	34·00	19·20	6·80	74·00	26·00

The looseness and high porosity is related to the high sand/clay ratio 4:1, and, in addition, to the high humus content and the calcareous nature of the substratum. There is no relation between structure and depth, a further indication that the soil is young.

The high moisture content is a contradiction of the mechanical analysis, which shows, instead of a clayey soil, a light friable soil; a fact confirmed by examination of the soil on the site. (This is probably related to the high humus content.)

Organic matter

The proportion of humus is high. Upper layer mildly acid, decomposition of the litter under Omorika is slow and the humification slow. Bacteria are probably not active. The moist conditions, heavy shade, and the acid state of upper layers create conditions which favour the fungi and their reaction.

Humus

Depth	% *Humus*
0–20 cm.	10·71
20–40 cm.	8·83

Chemical characteristics

pH

The soil reaction varies. There is a tendency to acidity in the top 15 cm.

Depth	*pH in Aqua*	*pH in n KCl*
0–15 cm.	6·45	5·48
16–35 cm.	7·21	6·66

Lime

Depth	% *Lime–CaO*
0–20 cm.	0·17
21–40 cm.	0·56

The soil is poor in lime, this is explained by the high humus content, due in turn to heavy fall of needles, greater than from other coniferous species, and the poor mineralization under unfavourable conditions for decomposition.

Analysis of other nutrients

Depth	P_2O_5 *mg/100 g.*	K_2O *mg/100 g.*	N
0–20 cm.	3·80	9·35	0·80
21–40 cm.	6·00	7·00	1·13

THE BRITISH ASSOCIATION, SHEFFIELD, 1956

The meeting is from Thursday, 29 August, to Wednesday, 5 September. Major items concerning forestry include the following:

Thursday, *a.m.* Joint Session with Section K (Botany). (Presidential Address 'Ecology of peat'.)
p.m. Excursion: Sheffield Corporation Waterworks.

Friday, *a.m.* Afforestation of water supply areas.
p.m. Excursion: Derwent Valley Waterboard plantations and Earl Fitzwilliam Estate (Bradfield plantations).

Saturday, Full Day Excursion: Whitwell Wood (Sherwood Forest), and Renishaw Estate.

Sunday, Full Day Excursion: Laughton Forest and Thonock Estate.

Monday, *a.m.* Joint Session with Section K on 'Decay of plant materials'.
p.m. Excursion: Chatsworth Estate.

Tuesday, *a.m.* Forestry in industrial areas, and smoke pollution.
p.m. Excursion: Local saw manufacturers.

Wednesday, *a.m.* Timber conversion: Sheffield saws.

Officers for 1956. Forestry Section

Chairman: Mr. M. V. Laurie, Chief Research Officer, Alice Holt.

Secretary: Mr. T. H. Owen, Dept. of Forestry, University College of North Wales, Bangor.

Local Secretary: Mr. J. Noel Wood, Manager, Sheffield Waterworks.

THE BRITISH ASSOCIATION, BRISTOL, 1955

The following papers were read in the Forestry Sub-section at the meeting of The British Association for the Advancement of Science held at Bristol in 1955. A joint session was held with Section K, the Botany Section, on the 5th September, when the subject was 'Fungi in Forests'. There were six excursions, of which the excursions to the Forest of Dean and to the Quantock Forest and Somerset willow-growing area were whole-day excursions.

Thursday September 1st.

Presidential Address to Section K by Professor K. Mather, F.R.S., 'Biological organization'.

Mr. K. G. Stott, 'The cultivation and uses of basket willows'.

Excursion to Long Ashton Research Station.

Friday, 2nd September.

Chairman's Address by Professor E. C. Mobbs, O.B.E., 'Afforestation and the community'.

Mr. A. H. Popert, 'The place of broadleaved trees in British forestry'.

Mr. C. M. Floyd, O.B.E., 'Hedgerow timber in the west of England'.

Excursion to Stokeleigh Forest, Bristol.

Saturday, 3rd September.

Excursion to Forest of Dean.

Sunday, 4th September.

Excursion to Quantock Forest and Somerset willow-growing area.

Monday, 5th September.

Dr. I. Levisohn, 'Ways of studying the activity of mycorrhiza-formers in the soil'.

Dr. Lilian E. Hawker, 'Hypogeous fungi'.

Miss R. M. Godfrey, 'Some woodland species of *Endogene*'.

Professor C. G. C. Chesters, 'Fungal population of bark of living trees'.

Excursion to Westonbirt Arboretum.

Tuesday, 6th September.

Mr. D. H. Carstairs, 'Some use of timber in the aircraft industry'.

Mr. J. R. Aaron, 'Timber in river and sea defence works'.

Mr. Edward Barnsley, 'The use of timber by craftsmen furniture makers'.

Excursion to Pope's Wood, Cotswolds.

It is understood that the meeting in 1957 will be held in Dublin. The meeting in 1958 will be in Glasgow.

PRODUCTION IN THE SWEDISH SAWMILL INDUSTRY (AN EXAMINATION OF DR. BERTIL THUNELL'S STUDY)

By J. J. MACGREGOR

(*Department of Forestry, University of Oxford*)

IN *Tekniska Produktionsförhållanden inom Sågverksindustrien*, Svenska Traforskningsinstitutet Träteknik, Stockholm, 1953, Dr. Bertil Thunell presents a concise account of factors influencing the efficiency of eight representative types of sawmill operating in Sweden.

Much thought has been given in recent years in Britain to the most suitable way for the sawmilling industry to adapt itself to the type of raw material that it is likely to receive in the future and an examination of Dr. Thunell's study may be of interest to British foresters and sawmillers.

Since the preparation of this study was put in hand, there has appeared in *Unasylva*, volume 9, number 3, a brief account on the same subject by Dr. Thunell. This account does not cover entirely the same ground and, after correspondence with The Director, Forestry Division, Food and Agricultural Organization, it was decided to go ahead with publication.

For those who would refer to the original source, it is noted that Tables I to V in this paper are respectively Tables 1, 2, 3, 4, and 8 in the original. A new table, VI, has been built up from data scattered through the original text while Figs. 1 to 7 are the original Figures 22, 23, 24, and 25 combined, 18, 30, 31, and 34 respectively.

THE EIGHT TYPES OF MILL AND SOME ASSUMPTIONS

The study is limited to the following eight types of mill using:

1. A single circular saw.
2. A circular head saw with an edger.
3. A circular head saw with a circular resaw and an edger (complete circular-saw mills).
4. Two circular head saws with two circular resaws and one edger (double complete circular-saw mills).[1]
5. A frame-saw.
6. A double frame-saw.
7. Two double frame-saws.
8. Three double frame-saws.[1]

Many assumptions are made for the comparisons—some of these can be inferred from the data in the several tables in the study. One is that all the sawmills considered are fully modern and have been intelligently planned—a point of great importance when considering circular-saw mills since these in practice often have relatively small capital sums invested in them. It is also assumed that each type

[1] Not shown in Tables I to III and V of this paper.

of mill produces export quality. The economic calculations are based on 1947–8 costs when, for example, average earnings of a worker were 2.30 crowns per hour (including holiday pay). Other assumptions are that sawing is carried on over 280 days in the year for each type although, for all but some of the larger frame-saws, statistics show the number of days to be very much less but actual time is also taken into account; that the sawn timber is air dried in open yards; and that four and six frame mills are fitted with gantry cranes. Depreciation is calculated after allowing 3 per cent. interest on capital and 1·5 per cent. for insurance and giving a life of 5 years for a single circular saw, 8 years for a complete circular-saw mill, and 15 years for a frame-saw mill. The formula for estimating the cost of equipping a complete circular-saw mill is put at: (1) $30{,}000+45\ (x-600)$ crowns and (2) $50{,}000+45\ (x-1000)$ crowns for mills having one circular saw and two circular saws respectively, where x represents the number of standards produced per year.

The cost analysis as shown in Tables I–III includes details under main headings as follows:

Cost of labour.
The actual payroll.

Cost of operation.
Cost of labour, power, operational repairs, and materials used indirectly in operation.

Production costs.
Cost of operation, depreciation, interest, and insurance on installations.

Administration, &c.
Cost of administration, sales organization, indirect labour, and social expenditures.

Mill costs.
Cost of administration, &c., material used indirectly, power, internal transportation, water, repairs, and insurance.

Additional costs.
Additional administration costs, &c., repairs, timber sorting, rolling and storing, lower production, and lower prices.

Overall cost of manufacture.
Production costs, additional costs, and cost of raw material.

THE EFFECT OF EXTERNAL FACTORS

In this section of the study are considered in turn (1) obtaining and preserving timber; (2) transportation of timber and sawn timber; (3) the dimensions and lengths of timber; (4) social amenities, administration costs, &c.; and (5) the spread and variation of the costs.

It is claimed that the best method of storing the round timber is to keep it in a water basin as this greatly helps sorting. The water also prevents the growth of fungi and reduces any tendency to split. Where timber has to be stored on land it is usual to instal a system of sprinklers. Where there is a permanent sprinkler

installation the cost is likely to be about 6.50 crowns per standard of sawn timber or about 5.60 crowns where a temporary system is installed. The cost of sorting the timber preparatory to sawing ranges upwards of about 4.00 crowns to 9.90 crowns per standard of sawn timber.

Circular-saw mills have a marked advantage in that timber does not need sorting for preliminary sawing as the best methods involve the mixing of the various sizes of logs. On the other hand, frame-saw mills need to have the timber sorted in advance so that the raw material can be used economically. One of the drawbacks of a frame-saw mill is that it has to have a sufficient reserve of logs before sawing commences in order that an adequate number of logs of similar dimensions can be sawn in one period of operation. This larger reserve implies a higher cost and a greater risk of deterioration during the storage period. The actual amount of interest on capital involved varies according to whether the operations are continuous or periodic but at 4 per cent. should not exceed about 10 crowns per standard of sawn timber. Modern chemical treatments, costing about another 5 crowns per standard, can reduce greatly the loss from stain damage from a possible 50 crowns to about 10 crowns per standard.

In south and central Sweden road transport now takes the bulk of the timber in these areas. The cost over short distances of water and of motor transport is approximately equal, but the latter has the disadvantage that with it the logs sometimes collect sand and gravel and washing may be necessary. Owing to a greater throughput of a frame-saw mill compared with a circular-saw mill an area of about 3·5 times as large will be required, and where there is no water transport the average length of haul will be increased from 20–25 to 40 kilometres respectively. Where it is necessary to store timber in a nearby lake the cost might be put at 40 crowns per standard, when the lake is within 5 kilometres from the mill for the proportion stored in this way. An average of 20–35 crowns per standard depending on distance is involved in transportation from mill to the ports. The greater value of sawn, as compared with raw timber, stresses the advantage of having the mill as near to the source of raw material as possible.

Although a standard log of 15 feet with an 8-inch top diameter is assumed in the calculations, in many of the mills on the Smaland plateau the timber is smaller. The volume of timber produced declines rapidly when the average size of the timber decreases and the cost increases. A point is made that circular-saw mills can compete better when there is some variation in the dimensions of the logs—although it is an advantage, within limits, to have a larger rather than smaller diameter. Frame-saws are more mechanized and can handle larger diameters more conveniently than circular-saw mills, and have an advantage in dealing with long timber.

Considerable differences exist between the conditions of employment in the different types of mills but reference is only made to a few of these conditions which more directly affect production and costs. In order to retain sufficient labour it is found necessary to give employment all the year round, a point which is easier for the larger type of mills. Many of the smaller circular-saw types move around the country and each move might cost 600 crowns, or about 1 to 10 crowns

TABLE I. *Comparison between various types of sawmill*

Type of mill	*Single circular-saw mill*	*Circular-saw mill with edger*	*Complete circular-saw mill*	*Single frame-saw mill*	*1 double frame-saw mill*	*2 double frame-saw mills*
Production						
standard/hour	0·38	0·44	0·81	0·94	2·13	4·40
standards/8 hours	3·0	3·5	6·5	7·5	17·0	35·2
Assumed number of working days per year	280	280	280	280	280	280
Actual working days per year	150	150	150	150	200	287
Annual production in standards during actual working days.	450	525	975	1,125	3,400	10,100
Annual production in standards during assumed number of working days	840	980	1,820	2,100	4,760	9,850
Number of workers						
Mill	6·2	7·2	9·4	9	14	30
Lumber yard	7	7	12	13	25	40
Total	13·2	14·2	21·4	22	39	70
Cost of establishments in thousands of crowns						
Mill	12	20	65	160	310	1,250
Lumber yard	10	10	85	150	300	2,000
Total	22	30	150	310	610	3,250
Depreciation						
Years	5	8	8	15	15	15
Per cent.	23·3	15·7* 23·3*	15·7	9·9	9·9	9·9
Number of working hours per day						
Mill	49·6	57·6	75·2	72	112	240
Lumber yard	56	56	96	104	200	320
Total	106	114	171	176	312	560
Working hours per standard						
Mill	16·5	16·5	11·6	9·6	6·6	6·8
Lumber yard	18·9	16·1	14·7	13·9	11·8	9·1
Total	35·4	32·6	26·3	23·5	18·4	15·9
Standards per worker and hour	0·028	0·031	0·038	0·043	0·054	0·063
Labour costs per standard in crowns	81.20	75.00	60.50	54.05	42.30	36.60
Cost of power	4.50	4.50	4.50	5.00	5.00	5.00
Cost of operational repairs	3.00	3.00	3.00	3.50	3.50	3.50
Total	88.70	82.50	68.00	62.55	50.80	45.10
Depreciation in crowns						
Mill	2,800	3,140	10,200	15,840	30,690	123,750
Lumber yard	2,330	2,330	13,350	14,850	29,700	198,000
Total	5,130	5,470	23,550	30,690	60,390	321,750
Depreciation in relation to hourly production in thousands of crowns						
Mill	7·4	7·1	12·6	16·9	14·4	28·1
Lumber yard	6·1	5·3	16·5	15·8	13·9	45·0
Total	13·5	12·4	29·1	32·7	28·3	73·1

* 15·7 for mill, 23·3 for lumber yard.

Type of mill	*Single circular-saw mill*	*Circular-saw mill with edger*	*Complete circular-saw mill*	*Single frame-saw mill*	*1 double frame-saw mill*	*2 double frame-saw mills*
Depreciation in relation to actual annual production in crowns per standard per year						
Mill	6.22	5.98	10.46	14.08	9.03	12.25
Lumber yard	5.18	4.44	13.69	13.20	8.74	19.60
Total	11.40	10.42	24.15	27.28	17.77	31.85
Investments in relation to hourly production in thousands of crowns						
Mill	31·6	45·5	80·2	170·2	145·5	284·1
Lumber yard	26·3	22·7	104·9	159·6	140·8	454·5
Total	57·9	68·2	185·1	329·8	286·3	738·6
Investments in relation to actual annual production in crowns per standards per year						
Mill	26.7	38.1	66.6	142.2	91.2	123.8
Lumber yard	22.2	19.0	87.2	133.3	88.2	198.0
Total	48.9	57.1	153.8	275.5	179.4	321.8

TABLE II. *Lumber yard costs in relation to annual production in standards*

Lumber yard costs in relation to annual production in standards	*Single circular-saw mill*	*Circular-saw mill with edger*	*Complete circular-saw mill*	*Single frame-saw mill*	*1 double frame-saw mill*	*2 double frame-saw mills*
200 investment	10,000	10,000	..	..	..	..
depreciation	2,330	2,330	..	..	..	..
400	10,000	10,000	30,000	105,000	..	..
	2,330	2,330	4,710	10,400	..	..
600	10,000	10,000	30,000	105,000	..	..
	2,330	2,330	4,710	10,400	..	..
800	10,000	10,000	39,000	105,000	130,800	..
	2,330	2,330	6,120	10,400	12,950	..
1,000	10,000*	10,000*	48,000	105,000	130,800	..
	2,330	2,330	7,540	10,400	12,950	..
1,500	..	..	70,500	127,500	153,300	..
	..	..	11,070	12,620	15,180	..
2,000	..	..	85,000*	150,000*	175,800	..
	..	..	13,350	14,850	17,400	..
3,000	..	..	..	..	220,800	1,692,000
	..	..	..	..	21,860	167,510
5,000	..	..	..	..	300,000*	1,782,000
	..	..	..	..	29,700	176,420
7,500	..	..	..	..	..	1,894,500
	..	..	..	..	..	187,560
10,000	..	..	..	..	..	2,000,000*
	..	..	..	..	..	198,000

* With maximum production according to Table I. It should be mentioned that the values have been calculated for the purposes of comparison and no consideration has been given, for example, to the practical limits of the number of working days during a year.

TABLE III. *Production costs in crowns per standard*

Type of mill (production in standards)	*Single circular-saw mill*	*Circular-saw mill with edger*	*Complete circular-saw mill*	*Single frame-saw mill*	*1 double frame-saw mill*	*2 double frame-saw mills*
200 cost of operation .	88.70	82.50	..	..	..	..
depreciation: mill	14.00	15.70	..	..	..	..
„ yard	11.65	11.65	..	..	..	..
Total .	114.35	109.85	..	..	..	..
400	88.70	82.50	68.00	62.55	..	..
	7.00	7.85	25.50	39.60	..	..
	5.85	5.85	11.75	26.00	..	..
	101.55	96.20	105.25	128.15	..	..
600	88.70	82.50	68.00	62.55	..	..
	4.65	5.25	17.00	26.40	..	..
	3.90	3.90	7.85	17.35	..	..
	97.25	91.65	92.85	106.30	..	..
800	88.70	82.50	68.00	62.55	50.80	..
	3.35	3.95	12.75	19.80	38.40	..
	2.80	2.80	7.65	13.00	16.20	..
	94.85	89.25	88.40	95.35	105.40	..
	840*					
1,000 . . .	..	82.50	68.00	62.55	50.80	..
	..	3.15	10.20	15.85	30.70	..
	..	2.35	7.55	10.40	12.95	..
	..	88.00	85.75	88.80	94.45	..
		980*				
1,500 . . .	..	..	68.00	62.55	50.80	..
	..	..	6.80	10.55	20.50	..
	..	..	7.40	8.40	10.10	..
	..	..	82.20	81.50	81.40	..
2,000 . . .	..	..	68.00	62.55	50.80	..
	..	..	5.10	7.55	15.35	..
	..	..	7.35	7.10	8.70	..
	..	..	80.45	77.20	74.85	..
			1,820*	2,100*		
3,000 . . .	..	..	..	..	50.80	45.10
	..	..	..	..	10.25	41.25
	..	..	..	..	7.25	56.00
	..	..	..	..	68.30	142.35
			2,800*			
5,000 . . .	..	..	..	..	50.80	45.10
	..	..	..	..	6.45	24.75
	..	..	..	..	6.25	35.30
	..	..	..	..	63.50	105.15
					4,760*	
7,500 . . .	..	..	..	..	..	45.10
	..	..	..	..	..	16.50
	..	..	..	..	..	25.00
	..	..	..	..	..	86.60
10,000 . . .	..	..	..	..	..	45.10
	..	..	..	..	..	12.55
	..	..	..	..	..	20.10
	..	..	..	..	..	77.75
						9,850*

* See footnote to Table II. Maximum production per annum for this type of mill.

per standard of the likely production. While communal facilities like laundries, meeting-halls, canteens, changing-rooms, &c., are the general rule at some of the larger mills—with expenditure amounting to between 4 and 10 crowns per standard—they would only be built by smaller mills in exceptional circumstances. For small mills with less elaborate arrangements the administration costs could be put at about 2.50 crowns, for medium-sized mills at between 4 and 7 crowns, and for the largest mills this expenditure, including foreman's salaries, managerial expenditures, works offices, sales and head office costs, at about 7 to 20 crowns per standard. Repairs on some of the smaller mills are likely to be a small expenditure but with the increased mechanization of the larger mills repairs cost, including wages and materials, can be put at about 10 crowns per standard.

In Table IV are shown the results of a special survey made to cover operating costs in the Norrland Mills. Labour costs in the mills showed a variation of 9 crowns at the most while the mill costs, excluding the cost of steam drying, had a maximum variation of about 39 crowns per standard. These data do not include interest and tax expenditure because the scantier book-keeping methods of some of the smaller companies with circular saws ruled out any real comparison. Much of the difference was due to the great range in fire insurance which in turn depended on differences in storage facilities and investments in establishments.

Evidence about the cost of steam drying is based on a report of a Norrland Committee on Sawmill Operations which drew attention to the fact that the lowest expenditure on wages was found in mills with steam drying facilities in combination with gantry cranes or in mills with steam drying and storage facilities only. This was offset by higher fuel expenses amounting to about 15 crowns per standard, although from this sum about 10 crowns could be deducted for reduced interest charges due to a quicker turn-over, reduced storage insurance costs, and the sales advantage of accepting orders although the required specifications may not then be in stock.

While, for the small mill, the advantage of the steam drying facilities might be too costly, drying facilities for at least part of the output have many advantages since they make possible the speedier production of sawn timber to special specifications. The recent development of high temperature methods, requiring much less equipment, and drying in a shorter period should become more popular.

Some changes in relative costs are shown as percentage variations for the period from 1911 (see Fig. 1), for sawyers' piece-work income, production per frame-saw, labour costs per standard for production and shipping, and investment costs for a given annual production, and for the cost of machinery, cost of construction, and cost of living. After 1922, wages have shown a tendency to rise but labour costs per standard sank greatly during the first half of the thirties due to wide-spread rationalization and modernization of the operations, meanwhile the cost of machines has increased (Fig. 2). The output of sawmills increased from about 0·7 standards in 1911 to about 2·2 standards per frame-saw hour for timber of the same dimensions. One of the results is that the number of frame-saws has been reduced while the capacity of the mills has been maintained or increased. Changes in the prices of round timber from 1911 to 1949, and the relation of these prices

TABLE IV. *Labour and works costs in crowns per standard for various types of frame-saw mills*

Mill no.	*Av. cu. vol. of timber when floated ft.³ 1945*	*1938 Labour costs*			*1945 Labour costs*			*Works costs**	*Total**
		Sawing and stacking	*Dispatching*	*Total*	*Sawing and stacking*	*Dispatching*	*Total*		
1	2	3	4	5	6	7	8	9	10
1	6·9	statistics not available			24.81	11.12	35.93	47.85	83.78
2	6·8	12.81	7.88	20.69	21.48	12.30	33.78	33.62	67.40
3	7·0	14.49	11.55	26.04	17.95	11.37	29.32	23.62	52.94
4	6·4	19.95	7.16	27.11	23.20	7.91	31.11	35.53	66.64
5	7·8	21.86	12.07	33.93	23.36	14.82	38.18	62.75	100.93
6	8·4	16.58	10.75	27.33	21.90	13.34	35.24	37.44	72.68
7	6·0	18.36	10.09	28.45	24.21	12.69	36.90	51.65	88.55
8	8·0	13.32	12.04	25.36	15.94	13.36	29.30	38.75	68.05
9	6·8	14.93	9.64	24.57	22.09	12.92	35.01	31.15	66.16
10	6·3	statistics not available			23.87	13.13	37.00	42.06	79.06
11	6·3	14.62	6.53	21.15	23.62	11.42	35.04	33.68	68.72

* Excluding any steam drying costs.

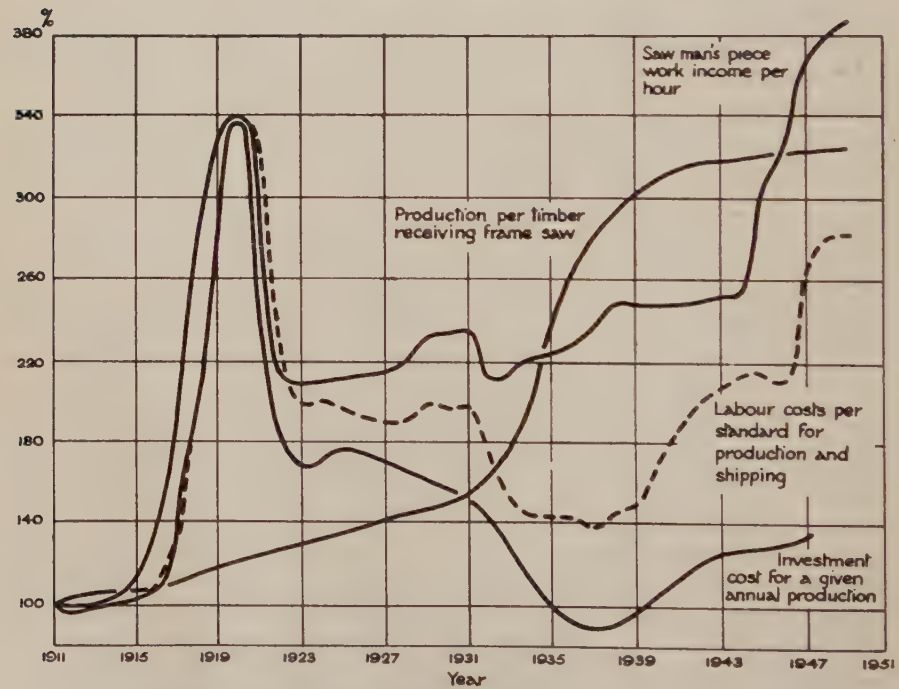

FIG. 1. Percentage variations in labour costs, incomes, investment and production costs during the years 1911–51.

to the hourly wage of a saw man is shown (Fig. 3). The years 1921 and 1931 showed low points after which wages rose considerably more than timber prices.

THE INFLUENCE OF INTERNAL FACTORS

Three internal influences are considered in this section: (1) the consumption of raw material, (2) the utilization of waste, and (3) the total production costs for various types of mill excluding the cost of raw material.

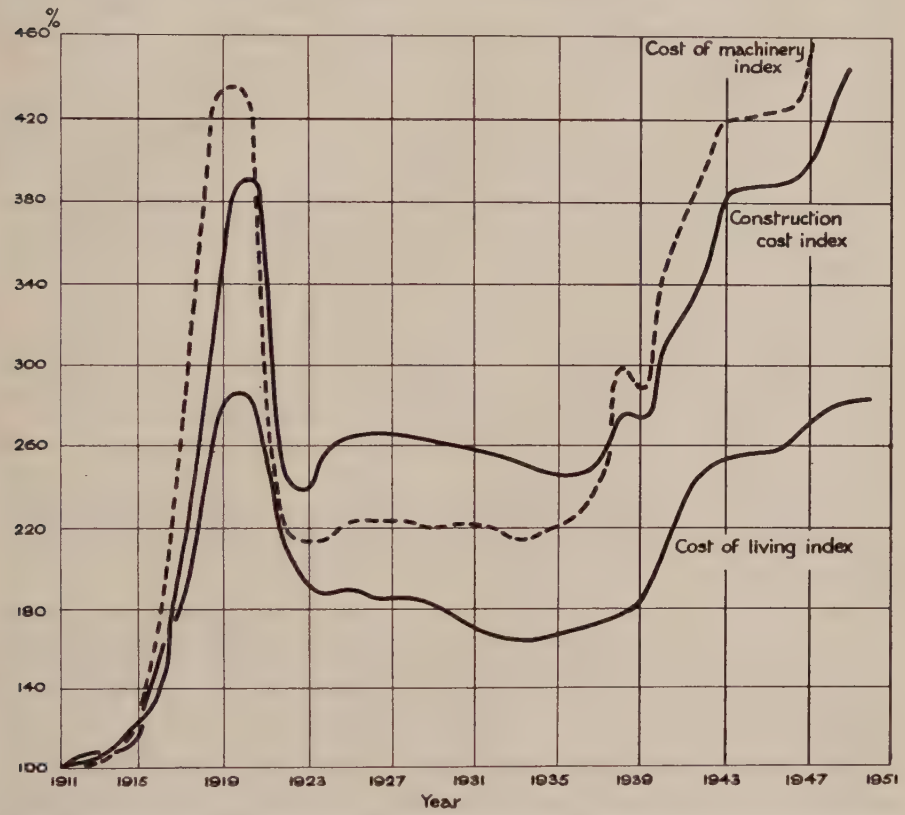

Fig. 2. Variations in the cost of living, cost of construction, and the cost of machinery indices during the years 1911–50. (1911 = 100.)

The consumption of raw material

As might be expected, different methods produce different yields of sawn timber from the same volume of unconverted timber. When a frame-saw is used this involves 'mass production' and the logs are sawn to a fixed sawing diagram. The best that the operator can do in these circumstances is to feed it on the side which he considers it to be the most suitable. Where the sawing is done by circular saw the operator has more flexibility in his choice and can change the sawing diagram according to any defects in the logs. No close measure has, however, been made of the additional yield which might be obtained from selective sawing

of this kind. As the yield, quality, and so on varied because of such factors as log size and type, it would in any case be difficult to get comparable conditions for true measurements of yield. The following representative data on yield are based

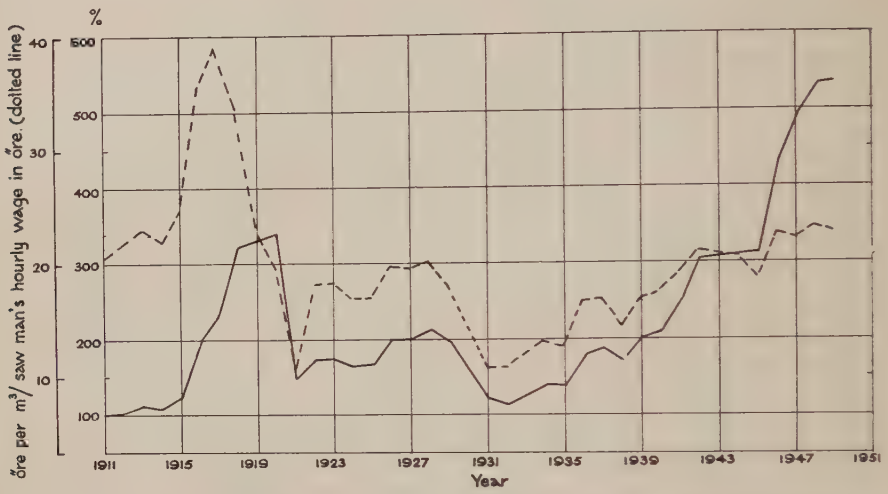

Fig. 3. Variations in the price of round timber, unbarked pine, top diameter of 8 inches (1911 = 100) and the relation between the price of round timber and wages (saw man's hourly rate) from 1911 to 1949.

on an 8-inch average top diameter without bark after sawing measurements have been made, all the percentages being calculated on the basis of mid-point measured total volume without bark:

Product	*Average calculation*	*Complete sawmill*	*Single circular saw*
Sawn timber	54	50	44
Sulphate chips	29	..	..
Sawdust	11	13	19
Firewood and blocks	3	..	..
Shrinkage allowance	3	3	3
Slabs, edgings, and end trimmings	..	34	34
	100	100	100

Sawdust losses and inaccurate cutting—due to the larger amount of handling involved—are greater for circular-saw mills. Diagrams in the original study clearly show that the average yield of circular sawing is lower than that of frame-sawing. As the production of export quality timber only is considered the diagrams do not, however, take into account the possibility that circular-saw mills may cut slabs and portions into small-sized timber. The extra consumption of raw materials was estimated at 24 cu. ft. for a complete circular-saw mill and at 30 cu. ft. for a circular-saw mill with edger, or an extra cost of 28.80 and 36.00 crowns per

standard respectively compared with frame-sawing. The curves in Fig. 4 take these differences into consideration.

On the one hand a special advantage claimed for the circular-saw mill is that it can switch to the production of special sizes of timber without great difficulty, and this may be important for local markets. On the other hand, apart from the fact that the yield from circular mills is technically lower than from frame-saw mills, their output usually fetches a lower price which is put at about 40 crowns per standard.

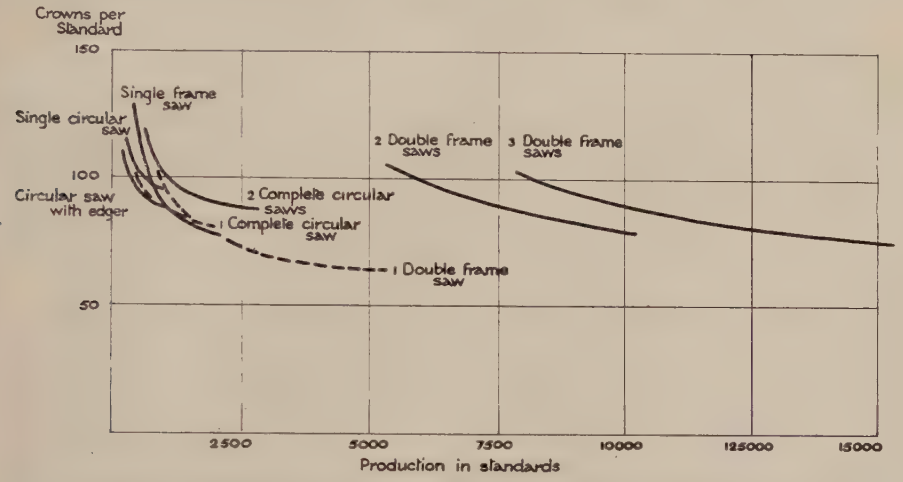

FIG. 4. Relative production costs of the various types of mill, cost of work on the saws, in the timber yard, dispatching, and depreciation, but excluding cost of raw material, administration and certain other general expenditures (see Tables I–III).

Bevel edging is more extensive with circular-saw mills. This reduction in quality does not play a decisive role in the home market and it is an advantage to the smaller mill to be able to use this method of increasing their yields and so compensating to some extent for the technical superiority of the frame-saw mills for yields. In view of the more complete utilization of waste there is not the same urgency for the larger mills to increase their yields in that way. The study emphasizes that the ability of the circular-saw mill to suit the market and to adapt itself to the timber available, thus making the completest use of it, combined with low fixed costs, may mean that the actual yield statistics for such mills are higher than those described. In other words, the circular-saw mills are to a certain extent able to hold their own in competition with the frame-saws.

A disadvantage of circular-sawn timber is that it is not so precise in its specifications as the frame-sawn timber although methods of sawing parallel cuts have improved greatly. It is, however, true that the quality of the out-turn from a circular-saw mill depends more on the skill of the operator than in a frame-saw mill, and in view of the general shortage of fully skilled men the need for suitable methods of training has to be borne in mind.

A related point is that in general the small mills do not take quite the same care

in shipping their sawn timber, and the evidence suggests that the small mills suffer more through losses from shrinkage and deviations from required specifications.

In Norway, where circular saws are widely used, the Norwegian Institute of Wood Research in Oslo found that, with a good saw and a highly skilled man, the circular-saw mill for all practical purposes cuts just as accurately as a frame-saw but there will be considerable variations in the result. Apparently accuracy tends to decrease as dimensions increase. One of the problems with circular-saw blades is that the efforts to save wood lead to the use of thin saw blades which give rise to difficulties in keeping up smooth operation when the speed of sawing is increased.

The utilization of waste

The degree of utilization of waste products has a considerable bearing on the economy of the individual methods of sawing. It is clear that the economic utilization of waste products depends on the scale of operation. Although some measure of the effect of scale can be inferred from the data in Table V it seems worth while to follow in some detail the arguments in this section of Dr. Thunell's report.

In the larger mills of the type found in Norrland the utilization of waste is scarcely a problem: sawdust is used for fuel; edging and slabs are chipped for cellulose or press-board. However, a certain amount of preparation of the material such as removal of bark is essential before it can be used for cellulose. The equipment for debarking is expensive and thus only suitable for installation in large mills and equipment is usually associated with bark presses which reduce the water content in bark to about 55 per cent. and thus improve it as a fuel. The relationship between size of output, capital cost, and cost per standard produced have been estimated as follows for debarking machines and their operation:

Type of Mill	*Output (standards)*	*Capital cost (crowns)*	*Cost of operation and depreciation per standard*
Double frame-saw . . .	5,000	140,000–180,000	5.60–6.80
Two or three double frame-saws	10,000–15,000	>450,000	6.80
Larger mill	20,000	600,000	6.20

The value of bark in turn depends on the size of the mill, about 2,000 to 2,500 standards per year is the smallest for economic installation of a debarking machine. As a smaller machine than the first one indicated in the table cannot bark logs thicker than 15 inches, manual barking has to be allowed for these, and such work would increase the debarking costs to 6.20 crowns per standard. The cost of debarking entirely by hand at 13 öre per cubic foot of sawn timber would represent 21.50 crowns per standard.

In making a broad estimate of the total value of conversion waste certain assumptions had to be made about the value and volume of the individual by-products. The values ascribed to each cubic metre of the by-products were in Swedish crowns: chips, 15.00; sawdust, 1.50 (and 4.50 where 50 per cent. dry);

TABLE V. *Additional costs in crowns per standard*

Type of mill (costs)	*Single circular-saw mill*	*Circular-saw mill with edger*	*Complete circular-saw mill*	*Single frame-saw mill*	*1 double frame-saw mill*	*2 double frame-saw mills*
Administration, &c. .	3.00	3.00	4.00	9.00	17.00	20.00
Repair costs . . .	2.00	2.00	2.00	10.00	13.00	10.00
Timber sorting and rolling . .	6.00	6.00	4.00	15.00*	2.50	2.50
Timber storage						
Wetting . . .	..	..	..	..	..	5.50
Storage costs . .	5.00	5.00	5.00	10.00	10.00	10.00
Blue stain losses						
Timber . . .	5.00	5.00	5.00	10.00	10.00	2.00
Lumber . . .	..	..	..	7.00	5.00	2.00
Transportation of sawn lumber to port† .	25.00	25.00	25.00	25.00	10.50	2.00
Poor yield . . .	82.80	35.00	28.80	..	..	..
Poor price . . .	30.00	30.00	16.00	..	..	..
Total . .	133.80	86.00	64.80	61.00	57.50	52.00
Cost of debarking for a production of:						
1,000 std. . .	..	..	..	..	16.80	..
2,000 std. . .	..	..	..	..	9.80	..
3,500 std. . .	..	..	..	..	6.90	..
5,000 std. . .	..	..	..	..	6.80	10.00
7,500 std. . .	..	..	..	..	..	8.00
10,000 std. . .	..	..	..	..	..	6.80
15,000 std. . .	..	..	..	..	..	..
Additional costs including costs of debarking						
1,000 std. . .	..	..	..	..	74.30	..
2,000 std. . .	..	..	..	..	67.30	..
3,500 std. . .	..	..	..	..	64.40	..
5,000 std. . .	..	..	..	..	64.30	67.00
7,500 std. . .	..	..	..	..	..	65.00
10,000 std. . .	..	..	..	..	..	63.80
15,000 std. . .	..	..	..	..	..	..
Value of waste cellulose chips, sawdust, firewood, bark for fuel	..	..	..	105.00‡	120.00	120.00
Slabs, edgings, sawdust for fuel, small lumber from slabs .	92.00§	92.00§	92.00§	92.00§	92.00§	..
Slabs, edgings, sawdust for fuel . .	52.00	52.00	52.00	52.00	..	..

* Including the cost of handling the cants.

† Has not been counted in the additional costs.

‡ This amount has been decreased because costs of chipping has not been previously included in calculations regarding single frame-saw mills.

§ Compare with Table VI.

bark, 4.00; slabs—edging and trimmed ends with bark, 7.00; charcoal made from slabs, 23.00; and small size timber from slabs, 3.50. Except for fire wood which was calculated as solid volume, the volumes were calculated as loose-packed cubic metres. Four types of treatment were reckoned to produce the volumes of by-products per standard of sawn timber and the net value as shown in Table VI.

The value placed on the 'waste' products is to some extent dependent on the size of mill, and the larger mills, as in Section A of Table VI, can use specially equipped furnaces to consume bark and sawdust. As the debarking cost has to be deducted for the larger mills, it can be said briefly that the utilization of 'waste' products is worth about 120 crowns per standard.

Such intensive methods of using 'waste' are not, however, open to the smallest mills since their output of waste is not sufficiently great to be of interest to the cellulose or press board plants and sawmills have to be a certain size before they can economically install debarking and chipping machines. The possibility of combining the output of several mills is being explored. Some of the values placed on alternative uses open to the smaller mills are shown in Sections B, C, D of Table VI.

TABLE VI. *Volume of waste products and their value in Swedish crowns per standard of sawn timber produced*

Type of product	*A* *Large mill (Volume cu. m.)*	*B* *Complete circular-saw mill (Volume cu. m.)*	*C* *Where 'waste' is made into charcoal** *(Volume cu. m.)*	*D* *Where small-sized timber is cut from slabs (Volume cu. m.)*
1. Chips	6·3	..	..	..
2. Sawdust	3·2†	4·5	4·0	5·3
3. Firewood	0·26	..	..	..
4. Bark	3·3	..	..	..
5. Slabs	..	6·5	..	5·5
6. Charcoal made from slabs	..	..	2·9	..
7. Small size timber from slabs	..	..	..	16·5
Value of Product	(Sw. crowns)	(Sw. crowns)	(Sw. crowns)	(Sw. crowns)
Total value	124.83	52.25	72.70	104.20
Less charring cost	..	..	24.60	12.00
Less transport cost	..	..	2.50	..
Net value	124.83	52.25	45.60	92.20

* The market for wood charcoal has since become relatively poor and the prices given are probably unrepresentative.

† It is only for the large mill in A that the sawdust is taken to be 50 per cent. dry with the higher value at 4.50 crowns.

In view of the percentage yields, 'waste' products were estimated on the assumption that if timber was sawn according to the same sawing diagrams it would be fairer to expect profit or utilization to follow the method according to

Section D of Table VI rather than according to Section B (i.e. at 92.20 rather than at 52.25 crowns). Thus the value of 'waste' products to the smaller mill could be put at 30.0 crowns lower than the larger mill.

From the estimated costs of production and prices of chips and firewood it was inferred that there was a possibility of collecting chips from several small mills—provided they could debark their timber economically—and the cost of transport was lower than about 5.50 crowns per loose-packed cubic metre of chips. While it

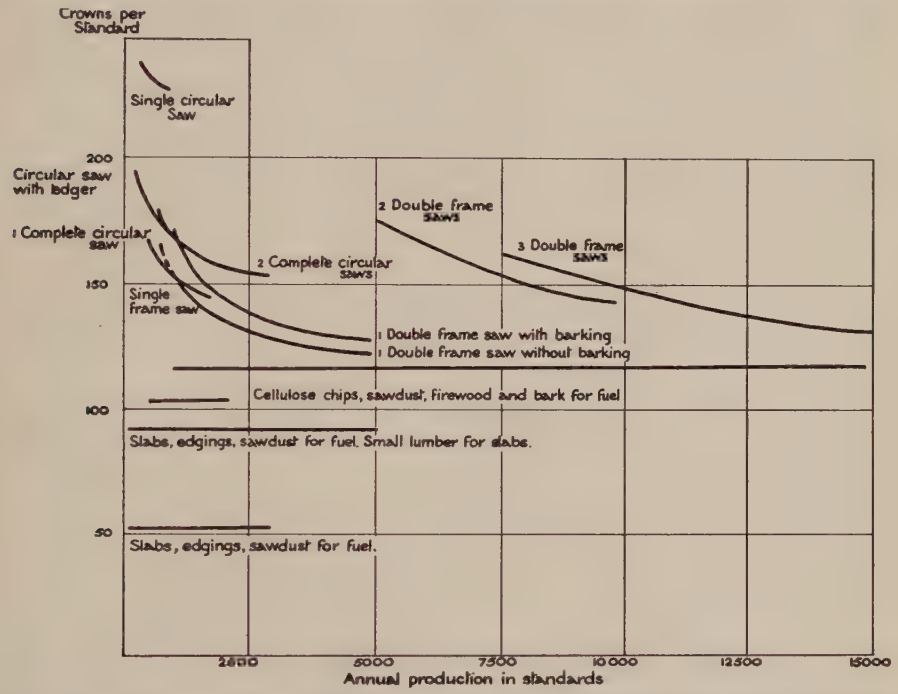

FIG. 5. Relative production costs, excluding cost of material, for mills of various types allowing for external and internal factors and the value of waste material.

might be doubtful, in view of the present organization of the smaller mills, if a cellulose plant would rely greatly on them for any significant proportion of its raw material, there were possible compensations in the amount of raw timber likely to be available. It thus appeared that the problem was one of organization rather than of technique. To a large extent the production of small timber was dependent on sufficient labour and this in turn implied that only the most highly mechanized methods could be used.

The total production costs for various types of sawmill excluding the cost of timber

Some of the influences which have been analysed above refer to costs in addition to those shown in Tables I to III and these are set out in Table V. The curves in Fig. 5 differ from those in Fig. 4 since they allow for the extra costs shown in Table V and take into consideration the value of waste and net cost for each of the eight types of mill.

The size of annual production

As the annual production of mills increases so also does the supplying area and thus the cost of transport, and this involves a decision about the kind of mill best suited for a given scale of production. Whether to employ one, or several, large mills—or a greater number of smaller mills—depends on factors which are not easily measurable. The study, however, considers the influence of transport costs in an ideal case in which the mill is situated at the centre of a circular homogeneous harvest area, in which it takes 3·6 square kilometres—including fields, roads, &c. —to produce one standard of sawn timber per year. These assumptions provide the straight line graph in Fig. 6, and show, where it is possible to arrange transport purely radially from the mill, the average length of haul required for a given annual production.

To simplify the calculation it is assumed that all transportation is by road, and that the average yield is 50 per cent. With the use of the scale for transport costs over different distances the cost of transport per sawn standard can be calculated (Fig. 6).

From the various cost estimates illustrated in a series of diagrams, which, for reasons of space it has not been possible to include in this article, are derived the total of transport and sawing costs and these are shown in Fig. 7.

One of the achievements of the study is to postulate for certain levels of production the type of mill which operates at lowest cost. As can be determined from Fig. 7 the following data show the ranges of most efficient use:

Output in standards per annum	*Most appropriate type of sawmill*
0–50 . . .	Single circular saw.
51–200 . . .	Single circular saw with edger.
201–975 . . .	Complete circular-saw mill.
Above 975 . . .	Frame-saw mills.

The cost of fully utilized frame-sawing with one, two, or three double frame-saws is relatively similar when there is a minimum production of about 2,500 standards per year. The distance between the respective curves in Fig. 5 and the line representing the value of waste can be taken as a measure of the production costs, and this clearly shows the advantage of having production on a sufficiently large scale to make the most economical use of the 'waste' wood. Although the series of cost data relate to 1947–8 the relative change in the movement of individual costs of labour, investment, and material which have been measured from 1911 onwards (see Figs. 1 and 2) makes it clear that an ever-increasing effective use of the raw material is necessary.

The available information suggests that most mills in Sweden are working below their economic capacity, the average production for frame-saws for the country as a whole being measured at 1,000 standards per year, with averages of 1,700 and 500 standards in northern and southern Sweden respectively; for circular saws the average was put at 130 standards per year.

In assessing the value of the data in the study it is explained that the estimates given cover a wide range and individual mills must be considered on their merits.

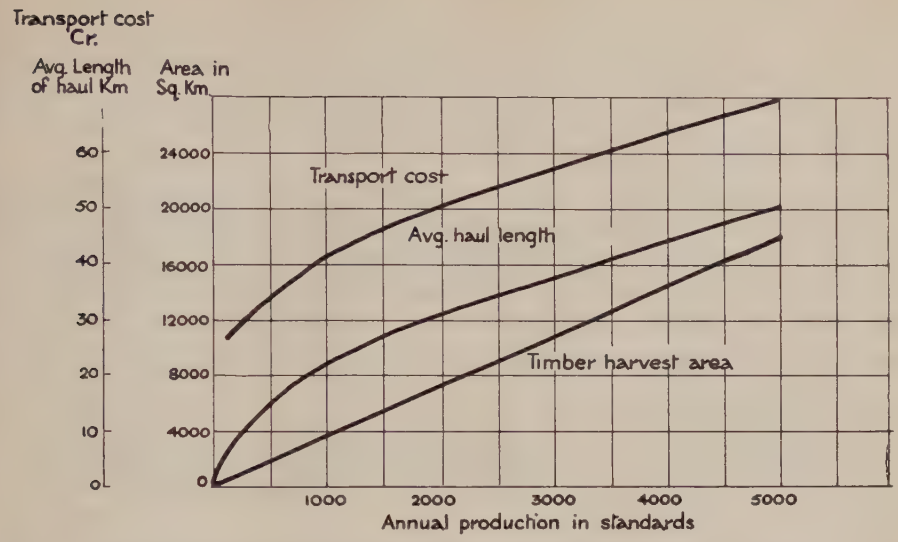

FIG. 6. Timber harvest area and the average length of road haul, and the cost of transport by lorry, including cost of loading and unloading, in relation to annual production.

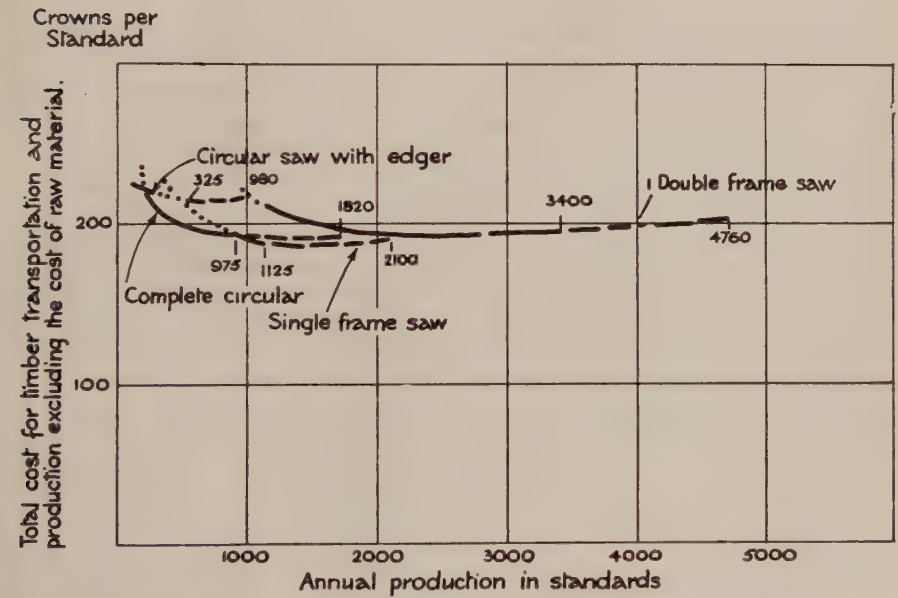

FIG. 7. Sawing costs (production costs excluding raw materials but including transport costs derived from Fig. 6) in relation to annual production. The various types of mills have been marked in the production area for which they are best suited. The solid lines represent production within the limits given in Table I about the limit of the number of working days, the broken lines represent the production possible if steps are taken to lengthen the period of production during a year. The dotted lines indicate production which can be maintained by another type of mill at lower cost.

The statistics do show, however, that the manner in which a mill is run plays a large part in its profitable operation. The need for training of all types of skilled staff is stressed. A number of technical problems in the industry are not yet capable of being solved because systematic compilation and studies of various materials did not begin until recently when they were started by the Swedish Forest Products Research Laboratory.

Perhaps rather surprisingly the data show that the differences in costs of the different sizes of mill are small. Clearly no great difficulty should arise in the provision of timber for the larger mills by using road transport. Yet the great significance of the mass transport of timber by water is emphasized. If the larger mills which use overland transport are to expand, the size and number of the roads in the harvest area must be adequate, and this is not always so at present.

ACKNOWLEDGEMENTS

Acknowledgement is due to Dr. Thunell for his assistance and to the Department of the Secretary of State for Canada for the opportunity given to examine its translation of the Swedish study.

FREDERICK KIRKWOOD MAKINS, M.A., F.L.S.

F. K. Makins died at Bruton in Somerset on the 7th of February this year. Since he retired from the Indian Forest Service, he had been actively engaged in forestry in the south-west of England, and probably did more for the establishment of co-operative forestry in England than any other single person. He gave up the secretaryship of the South-Western Woodlands Association about a year ago, but retained his interest and continued to do a great deal of the work. He was a frequent and distinguished reviewer of books. One of his own books, *The Identification of Trees and Shrubs* (1936), of which a second edition came out in 1948, is well known and is an accepted work of reference. It would, we feel, have pleased him to find it so used in the paper on *Picea omorika* printed in this number of *Forestry*.

Makins was the soul of modesty. He regarded himself first as a botanist and spoke quite recently of a further book on which he was working and which we hope will come to fruition. He will be remembered both as botanist and as forester and British forestry has lost one of its distinguished men.

THE SOCIETY'S VISIT TO DENMARK

By G. E. GODWIN

SUMMARY

A record, with particulars of the personalities met, and of the methods favoured, and the thinning régimes practised by the principal exponents of forestry in Denmark including the Dune Service, the Danish Heath Society, and some private estates which were visited under the guidance of the Director of the State Forest Service.

TWENTY-SIX members boarded the boat train at Liverpool Street station on Saturday the 17th September 1955 for the special excursion which lasted until the 24th and was under the leadership of the Vice-President, Mr. A. P. Long. At Esbjerg the party was joined by three more members, and was met by the Assistant to the Director of State Forestry, Kgl. Skovrider H. Frölund, our guide throughout the visit.

From Esbjerg we drove to Bordrup Dune Plantation and for the rest of the day were the guests of the Dune Service. At Ulslo we were welcomed by the Director, Mr. P. Thaarup, and his assistant. Director Thaarup was no stranger to us as he took considerable part in the British Association meeting at Liverpool in 1953. He told us of the work of the Dune Service, supplementing the notes supplied to the party. Both here and at each district or organization visited, most useful and informative notes were supplied to us.

There are 185,250 acres of sand dune along the west coast of Jutland, of which the State owns 103,750 acres; of this, again, 71,360 acres have been afforested. About a quarter carry or will carry economic crops of Sitka spruce (*Picea sitchensis* Carr.), silver fir (*Abies alba* Mill.), Scots pine (*Pinus sylvestris* L.), and even hardwoods; in all cases after an initial crop of mountain pine (*P. mugo* Turra). A rather larger area will carry less exacting species such as erect mountain pine, *P. contorta*, Austrian pine (*P. nigra forma austriaca*), and a little Scots pine. The remainder will support only spreading mountain pine, or cannot be planted at all. Planting with spreading mountain pine to fix the sand has been given up as too expensive and marram grass is now used. Afforestation is now confined to areas where reasonably satisfactory timber crops can be grown. Of the mountain pines, only the erect variety is used. Remnants of Scots pine planted in 1851 were seen; the progeny from these trees is proving faster growing and more tolerant than most other provenances tried. Young Scots pine of Gordon Castle origin was also seen, and during a discussion, Director Thaarup expressed the view, which caused some surprise, that one of the most hopeful provenances for Jutland was Achnashellach. Corsican pine (*P. nigra* var. *calabrica*) is not used; it is not grown on any great scale in Denmark. Austrian pine grows reasonably well but is subject to *Brunchorstia*. Norway spruce (*Picea abies* Karst.) is not used here as it does not stand up to the sea winds.

Vrögum Dune Plantation was next visited. This is more fertile, the sand over

lying a moraine layer of sand mixed with clay, accessible in places to tree roots. Some oak had been used here, and also birch, which regenerates freely. Stands of 20-year old Japanese larch (*Larix leptolepis* Murr.) were seen, following on mountain pine or Sitka spruce. Some Douglas fir (*Pseudotsuga taxifolia* Brit.) was seen, planted on old arable land in 1899, and now carrying 3,030 cu. ft. per acre with a current annual increment of 202 cu. ft. per acre. This was originally mixed with mountain pine, which did not survive. Adjoining it was a 1951 plantation of Douglas fir, Sitka spruce, and Japanese larch; the Douglas fir suffered from frost last winter and the larch from drought this summer. We climbed the high dune 'Storehöj', and were overtaken by the only rain encountered on the entire excursion. An extensive view was had over the plantations, and we were impressed by the difficulties of practising forestry in these inhospitable surroundings, where unremitting sea winds, cold winters, spring frosts, and summer droughts combine with infertile sites and moving sand to tax the foresters' skill and patience.

Sunday night was spent at Varde, where Director Thaarup entertained the party to dinner on behalf of the Dune Service. He expressed his pleasure at our visit, and Mr. Long, in reply, spoke of the interest and admiration felt by members at what they had seen.

The Danish Heath Society

On Monday morning we drove to the Danish Heath Society's 7th District in Mid-Jutland, and were met at Hovborg by the Chairman of the Society, Hofjaegermester Chr. Lüttichau, the leader of the Planting Division, Skovrider B. Steenstrup, and the District Officer, Skovrider C. G. Bech, together with Skovrider E. C. L. Löfting, leader of the heath and dune forest section of the State Forest Research Branch. The Danish Heath Society and its work are well known. Founded in 1866, largely through the vision and energy of one man, Enrico Dalgas, the Society set out to promote the reclamation to agriculture or forestry of the then extensive heathlands in Jutland. In 1850 these amounted to 2½ million acres; in 1952, 494,000 acres remained, some areas still to be reclaimed, others now to be preserved in their natural state. Apart from the large area reclaimed to agriculture, the Society has been instrumental in the planting of over 200,000 acres, of which some 30,000 acres are owned by the Society. A further 54,000 acres of plantation are managed by the Society, and there is an extensive system of inspection and advice in the case of innumerable smaller plantations, and in particular in the case of the vast network of shelterbelts planted and still being planted throughout Jutland. State aid is available for planting, but the foundation and pioneering work of the Society are a splendid example of the best kind of private enterprise. The impetus was provided by the loss to Germany in 1864 of Schleswig-Holstein; the motto became: 'What has been lost without must be won within.'

The party visited Hovborg, Höllund Sögaard, and Fromsseier Plantations, all in private ownership but managed by the Society, and Slauggaard Plantation, owned by the Society. All these lie on the rather better eastern type of heath, where the ground is slightly undulating and Norway spruce grows tolerably; to

the west the heath becomes flat and poorer, and Norway spruce is not happy. The rainfall in this locality is between 29 and 30 inches, compared with the Danish average of 24·4 inches. Almost all the plantations seen were originally planted in mixture with mountain pine, or had succeeded a crop of mountain pine. Regeneration of old mountain pine stands is not easy as heavy thinning or felling leads to extensive outbreaks of *Myelophilus piniperda*.

It was very noticeable that the commonest form of shelterbelt on agricultural land was a single row of trees, Sitka spruce having largely superseded white spruce (*Picea glauca* Voss.) and other species for the purpose.

In Hovborg Plantation a wedge regeneration of old Norway spruce was in progress, and we were shown the now famous Danish practice of ignoring dense natural regeneration of Norway spruce and planting Norway spruce through it! Admittedly some Japanese larch were also being planted as nurses, but natural spruce were being dug up and replanted, and demonstrably set off at an improved rate of growth.

In Höllund Sögaard various crops were seen growing on former heath, agricultural, and oak scrub land; a good deal of the initial crop was mountain pine, with some Norway spruce and silver fir on the better sites. The old mountain pine areas are being regenerated mainly to Norway spruce, often with 15 per cent. of silver fir added; Sitka and white spruce, Japanese larch, silver fir, *Pinus contorta*, and birch are also used. A pleasing stand of 62-year old Sitka spruce was seen, originally mixed with mountain pine and silver fir, some of the latter still surviving. In 1952 this stand carried 130 Sitka and 38 silver fir to the acre, the Sitka being 78 feet and the silver fir 57½ feet high, and the volume per acre being 4,240 cu. ft. spruce and 303 cu. ft. silver fir. A soil pit showed good rooting depth, and the resulting vigour of the trees had so far staved off any serious attack by *Dendroctonus micans*, the bark beetle scourge of Sitka spruce in particular, of which we were to see and hear much.

A demonstration was given of the 'Tolne' plough, a double furrow plough much used on heathland and felled woodland. This was drawn by a Bristol 22 tractor. It had the unusual feature of a roller mounted ahead of a saw-toothed coulter disk, the roller flattening the vegetation and branches for the disk to cut in tension, followed by a double mouldboard throwing a shallow ridge to either side of a furrow about 24 inches wide. Behind this was a subsoiler, the rear end of the main beam being supported on small rubber tyred wheels with a sprung saddle above, on which the ploughman's assistant sat somewhat uncomfortably. The cost of the ploughing was given as 80 to 120 shillings per acre. It appeared to be a most effective plough for this type of ground; planting is, of course, in the furrow and not on the ridge.

After seeing a good Norway spruce stand in Fromsseier Plantation, we drove to Skovrider Bech's official residence in Slauggard Plantation. There we were entertained to luncheon by the Heath Society, Fru Bech acting as our hostess. Professor Steven thanked the Heath Society and in particular the Chairman and those who were present for this most interesting day and lavish hospitality. Later, we walked through Slauggaard Plantation, the planting of which started in 1894 and which

is one of the better heath plantations; the main species is Norway spruce, planted mainly in mixture with mountain pine in subsoiled furrows, in some cases after complete ploughing of the heath. A nice 55-year old stand had an average total height in 1952 of 70 feet, with 288 trees to the acre, a standing volume of 4,488 cu. ft. per acre, and a current annual increment of 163 cu. ft. per acre.

Finally, we drove to Staldbakkerne on Randböl Heath, a large stretch of heath now preserved, and from there to Silkeborg for the night. Skovrider and Fru Bech, and Skovrider and Fru Löfting joined us there for dinner, after which Skovrider Löfting showed us a series of most interesting colour slides made by him, showing the effect of last winter's severe weather on Scots pine of many different provenances.

Tuesday, 20th September: Frijsenborg Estate

This lies in east Jutland, and is the biggest private estate in Denmark, totalling some 14,090 acres, of which 11,370 acres are woodland. It is owned by Countess Inger Wedell, who was unfortunately unable to be present, but her son Count Tido Wedell very kindly accompanied the party. The woodland area comprises some fifty different woods of all sizes, growing on varied soils ranging from pure sand to heavy clay; the crops consist of both conifers and hardwoods, a large part being young plantations following very severe windblows in 1934 and 1937, and compulsory war fellings.

The woods have been under highly skilled management for a very long time. The present manager, Overförster J. A. Lövengreen, who conducted the party, has been in charge since 1953, and inherited a tradition of active management and of frequent and cumulatively heavy thinnings. Control measurements have been kept for a long time. It has been shown that an increase in thinning grade has a beneficial effect at the start, both on the soil and on increment, including even height increment. With continued heavy thinning, it appears that there has been a falling off in increment, coupled with increased susceptibility to adverse factors such as wind, drought, and accompanying insect and fungal attack. Overförster Lövengreen was of the opinion that in many cases the basal area had been reduced to less than the optimum, and that maximum increment could only be obtained by working to the optimal basal area for each site.

The first stands seen were adjoining crops of *Abies grandis* and *A. nordmanniana* in Hagsholm Wood, the former 44 years old and the latter 46. Comparative figures are as follows:

	Age	*Height (ft.)*	*No. of stems*	*Diam. (in.)*	*Basal area (sq. ft.)*	*Vol. (cu. ft.)*
A. grandis (1952). .	41	81	151	14	158·8	4,376
A. nord. (1955) . .	46	53	536	7·8	182·6	4,410

The 1955 volume per acre of the *A. grandis* is 5,385, and to date 4,545 cu. ft. have been removed in thinnings, giving a total production per acre of 9,930 cu. ft. Periodic mean annual increment from 1931 to 1955 is given as 349 cu. ft. per

acre, and m.a.i. to date works out at 225 cu. ft. per acre. The usual discussion arose as to the merits and demerits of *A. grandis*; it was admitted that it made poor peeler logs, but no difficulties were experienced in selling as saw timber. Members liked the thinning of the *grandis*, which was a much superior crop to the *nordmanniana*. A large part of Hagsholm Wood was originally even-aged Norway spruce, now 55–60 years old; this is being regenerated on comparatively small areas, chiefly with beech and silver fir, with the object of breaking the evenness and introducing a greater variety of species. Here, as elsewhere in Denmark, large even-aged stands of single species are not liked—the object is to transform plantations into 'proper woods', not selection forest, but a patchwork of even-aged stands of modest size and different species. The rather sad remains of a 52-year old Sitka stand were seen; this had been heavily thinned from the start, and 20 years ago was a good stand, but a heavy attack of *Fomes annosus* led to underplanting with sycamore. *Fomes* was followed by *Dendroctonus micans*, and by windblow, exposing a stand of Norway spruce adjoining. The Norway spruce crowns were shortened by one-third to give increased stability; Mr. Long pointed out that in Britain such pruning usually had the opposite effect.

A good stand of 52-year old sessile oak of Spessart origin was seen in Haurum Wood. This carried 148 trees to the acre, with a mean height of 61 feet, diameter 8½ inches, basal area 60 sq. ft. and volume per acre 1,447 cu. ft.; it was (Danish) quality class II, and Overförster Lövengreen considered the optimal basal area to be of the order of 97 sq. ft. For veneer oak, which is always the aim of oak growing in Denmark, a price of 600 to 700 or more kroner per cubic metre is obtained, or about 23*s*. per cubic foot.

A stand of 48-year old Sitka spruce, said to be the best in Denmark, was also seen in Haurum Wood. The age of 48 was from seed, and we should reckon it at about 45 years old. It carried 148 trees to the acre, with a mean height of 99 feet, diameter 15·4 inches, basal area 191·4 sq. ft., and volume per acre 7,125 cu. ft. This was indeed a fine stand. It had been pruned in 1935, and the ground had recently been cultivated to break up the tight covering of *Deschampsia flexuosa*. There had been some *Fomes* and some *D. micans*, but the trees were vigorous.

We were most hospitably entertained to lunch, Count Tido Wedell presiding, in an idyllic forest restaurant at Pöt Mölle. Mr. Long expressed our thanks, and thereafter we drove past Frijsenborg Castle and through the deer park to an extremely fine stand of 50-year old Norway spruce. This carried 174 trees to the acre with a mean height of 81 feet, diameter 12·7 inches, basal area 159 sq. ft., and volume per acre 4,660 cu. ft. The periodic mean annual increment from 1936 to 1954 was 270 cu. ft. per acre. Questioned as to future treatment, Overförster Lövengreen said he was happy to retain until further notice a stand with an annual increment of this order.

Norringure Wood (see Plate IX) provided some interesting stands, in particular a 52-year old (50 years British reckoning) stand of Japanese larch, underplanted 17 years ago with *Tsuga heterophylla*. Three periodic measurements of the larch are as shown in the table on p. 142.

This shows a mean annual increment to date over its whole life of 146 cu. ft. per

	1916	1934	1954
Mean height, ft.	23½	64½	83
Diameter, in.	4	9·7	14·9
Trees per acre	1,150	127	69
Basal area, sq. ft.	100	61·5	77·3
Volume per acre, cu. ft.	1,030	1,747	2,700

acre. The picture was a most pleasing one, the larch being of good form and the Tsuga coming up well as a replacement crop.

Across the road from this were adjacent stands of silver fir and Douglas fir. The silver fir, 64 years old, were now reduced to 125 trees to the acre, a very much lower stocking than is usually found in Denmark; it had been kept dense up to the age of about 40, and the crowns were still small. Mean height (1953) was 84 feet, diameter 14 inches, basal area 137 sq. ft., and volume per acre 4,530 cu. ft. Periodic mean annual increment from 1928 to 1945 had been 275 cu. ft. per acre, from 1945 to 1953 168 cu. ft. The Douglas fir was an impressive stand, now 72 years old; the trees were (1954) 110 feet high, and the volume per acre 7,180 cu. ft. There were some splendid trees; at a stocking of 64 trees to the acre the average volume per tree was over 110 cu. ft.

This was the last stand seen at Frijsenborg. We had left the bleak west coast of Jutland where timber production was a secondary object of management. We had left the heathlands, where conditions were unfavourable and growth slow, and where the successful raising of the less exacting conifers was a creditable achievement. At Frijsenborg there was a wide range of sites and species; there were plenty of silvicultural problems, but the main problem was no longer that of establishing satisfactory tree crops. It was the proper management of a forest estate and the constant raising of standards and of yields. A long drive followed down the east coast of Jutland, and across the magnificent bridge spanning the Little Belt to the island of Fyn as the sun was setting, to end the day in the old town of Middelfart.

Wednesday, 21st September: Wedellsborg and Frederiksgave Estates

Wedellsborg is a considerable estate, owned by Count Julius Wedell, husband of the owner of Frijsenborg. The woodlands amount to 3,150 acres, of which rather more than half consists of conifers. It was the conifers we were to see, growing on a sandy, infertile ridge known as 'Wedellsborg Banks', in a region of low rainfall (22·6 inches). We were taken round by the woodland manager, Skovrider P. Quistgaard, whose enthusiasm and willingness both to answer and to ask questions made the day a most enjoyable one; Fru Quistgaard, too, accompanied the party. Here, again, there was a long tradition of skilled management. Skovrider Quistgaard's predecessor managed the woods for 40 years, and his predecessor again for over 60 years.

The first stop was at Örslev Plantation, where one- and two-year-old plantations of mixed silver fir (in this case *Abies nordmanniana*), spruce, and larch were seen, following on a crop of Austrian pine of which a few trees had been left standing.

M. V. Laurie

Norringure Wood, Frijsenborg Estate. Japanese larch, 50 years, under-planted with Tsuga, 17 years

PLATE IX

M. V. Laurie

Teglskoven, Frederiksgave Estate. Beech, 70 years, with understory of sycamore, beech, ash, and elm

PLATE X

A 30-year old stand of Scots pine of Scottish origin was seen, recently pruned to about 20 feet. It was interesting to see Austrian pine, and in places Corsican pine, not commonly grown in Denmark; in this locality Austrian pine timber fetched as much as Scots.

In Haare Plantation we saw a pleasing stand of 53-year old silver fir (*A. alba*), with a small admixture of Norway and Sitka spruce. The mean height was 66 feet, with a standing volume per acre of 3,645 cu. ft., and a current annual increment of 187 cu. ft. The total production to date was estimated to be in the region of 7,500 to 8,000 cu. ft. This stand was free from *Fomes*, and was registered for seed collection by the Danish Forestry Society's Seed Committee. The next stand seen, also in Haare Plantation, was in sharp contrast, namely, a 40-year old remnant of Sitka spruce. It had suffered fairly severely from *Fomes*, followed by *Dendroctonus micans*; up to 1947 it had been a reasonable crop, but the exceptionally long dry summer of that year proved its undoing. This was the last Sitka spruce we were to examine in Denmark, and many of us were puzzled that Sitka could be grown with such low rainfall and frequently on such dry sites. Some Danish foresters evidently considered the risk worth it owing to its rapid production but on Wedellsborg Banks, Skovrider Quistgaard would prefer to increase the area of silver fir.

This concluded the visit to Wedellsborg. The second estate in the day's programme, Frederiksgave, is owned by the Count Karl Wedell Foundation which most kindly entertained the party to luncheon at a country inn. Afterwards we walked through Teglskoven, which was for some the highlight of the tour. This consists mainly of 120-year-old oak and 70-year-old beech, the soil being a deep boulder clay; there is a natural understory of sycamore, beech, ash, and elm affording good soil protection, and an absence of grass. The past treatment of this wood has differed radically from the usual Danish treatment of hardwoods and beech in particular; from the first the crowns have been given room to develop, and the result is now seen in trees of big girth with splendid crowns. It is hoped that the beech will mature at 100 years instead of at 120 or 150. It was interesting to learn that though the number of trees to the acre was only 60 per cent. of the yield table figure (Danish quality class 1.3 to 1.5), the basal area was between 80 and 90 per cent. (Plate X).

It was explained that with the oak the aim was to produce a clean first length of 33 to 40 feet, of which the first 18 to 20 feet would be of veneer quality, fetching 20*s*. and up to nearly 30*s*. per cubic foot, the remainder of the timber length fetching 7*s*. to 11*s*. These oaks had a total height of 87 feet, and a mean mid-diameter of 26 inches; the stocking was 22 to 26 trees per acre, the understory containing a number of fair sycamore and beech especially. The volume per acre of the one section Compartment 1D was as follows (1953): oak 3,456 cu. ft.; beech 146 cu. ft.; understory 740 cu. ft. Total 4,342 cu. ft. This was an outstanding plot; volumes elsewhere of a slightly lower quality class and with a lower stocking were from 2,700 to 3,230 cu. ft. per acre.

Major Ackers expressed the party's appreciation of our host's kind hospitality and not inconsiderable envy of the magnificent woods that we had seen during

the day. Rather regretfully we left for Nyborg and the ferry across the Great Belt to Korsör on the island of Sjaelland, an enjoyable trip on a fine early autumn evening. The night was spent split up among several hotels in the town of Sorö.

Thursday, 22nd September: Sorö Academy's 1st District

The woods seen comprise one of two blocks owned by this famous public school. Management is under the Chief Inspector of Sorö Academy's woods, who is Director of State Forests, N. B. Ulrich. The District Officer is Kgl. Skovrider F. Lorenzen, who has managed the woods for 28 years. He was our most inspiring guide during the day, and Director Ulrich honoured us by welcoming the party and spending the day with us.

The first stand seen was a beechwood 130–40 years old now opened up for natural regeneration. This stood at 8,775 cu. ft. per acre in 1925, 7,740 cu. ft. in 1935, and 6,865 cu. ft. in 1945. The trees were good and ran to a mean height of 115 feet. Skovrider Lorenzen stated that 40 per cent. of the volume was contained in the first 26-foot length, but this represented 62 per cent. of the value; 57 per cent. was contained in the first 40 feet, representing 82 per cent. of the value. There was dense natural regeneration 12–15 years old; the ground was ploughed before the mast fell, and the mast then harrowed in. Apart from this, the only cost of the new crop had been two cleanings at 40*s.* per acre each.

A modern mechanized way of dealing with superabundant natural regeneration was seen in a dense crop of natural beech dating from 1948, the stocking of which was given as over 100,000 to the acre. An implement very similar to an autoscythe was put through it in strips, the cost being given as 20*s.* per acre. We were told that the total cost of a crop such as this, allowing for two cleanings by autoscythe and two by hand, was about 120*s.* per acre. No weeding was, of course, required.

To show that conifers could also be grown we were taken to a stand of 46 years old silver fir (*Abies alba*) which carried 156 trees to the acre of mean height 80 feet, diameter 12·7 inches, basal area 134 sq. ft., and volume per acre 4,430 cu. ft., the periodic mean annual increment from 1939 to 1955 being 306 cu. ft. per acre. This, like the Frijsenborg stand, was heavily thinned by Danish silver fir standards, and the trees were a little coarse, but would fetch a good price for piles.

Back to hardwoods, to see adjoining stands of oak of Dutch origin, 48 years old, and red oak, 45 years old. As was to be expected, the red oak were a fair distance ahead in every way, comparative figures being as follows:

	Oak	*Red oak*		*Oak*	*Red oak*
Height, ft. . . .	70½	76	Basal area, sq. ft. . .	51·4	59·2
Stems per acre . .	77	71	Vol. per acre, cu. ft. . .	1,730	2,210
Diameter, in. . .	10·8	12·4	Periodic m.a.i. 1942 to 1955 .	121	168

The number of trees per acre appears low, but there was a good natural understory of beech. The same price has been obtained for both timbers so far.

We then made our way to the Academy where luncheon was very kindly provided, the Principal himself being host. Afterwards, Professor Mobbs, who led

the party for the day, expressed our thanks to the Academy and its Principal, to Director Ulrich, and to Kgl. Skovrider Lorenzen.

During the afternoon we saw the effects of two degrees of heavier than normal thinning of Quality I beech about 60 years of age in Compartments 14B and 14A. The former had been thinned every other year for the last 25 years; compared with the yield table, although it only had fewer than half the number of stems, its basal area was two-thirds and its diameter 27 per cent. greater. In the latter, thinning had started later and was somewhat lighter and gave intermediate results. It was claimed that the earlier production of larger timber from the heavier thinning gave a better financial return. The comparisons are:

	14B	*Yield table*	*14A*
Age, years	59	59	57
Height, ft.	77	77	74
No. of stems	69	160	111
Diameter, in.	14·1	11	12·75
Basal area, sq. ft.	75·4	118·8	100
Standing volume, cu. ft.	2,245	3,365	2,670

At this point, we had to break off and leave for Copenhagen, where, in the evening, the Danish Forestry Society and the State Forest Service were joint hosts at a dinner given at 'Skovriderkroen' on the outskirts of Copenhagen, a most pleasant restaurant owned by the State Forest Service. The President of the Forestry Society, Kammerherre Iuel, was present with Fru Iuel, and Director Ulrich and Fru Ulrich, together with other well-known representatives of Danish forestry, forest research, and forestry education, including Dr. Syrach Larsen. Kammerherre Iuel addressed us, and so did Director Ulrich; the latter, referring to the number of foresters visiting Denmark from abroad every year, said that the total since the end of the war was now over 200; the 200th visitor was present on this occasion, and he proposed to make him a presentation. The 200th visitor turned out to be Professor Steven, and the present a parcel of selected Douglas fir seed from Oyster Bay, near Courtenay (Eastern Vancouver Island). Professor Steven replied warmly amid great applause, and finally Mr. Long expressed the very great appreciation felt by all the party at the quite overwhelming reception we had had. A memorable evening.

Friday, 23rd September: The State Forest Seed Extraction and Tree Improvement Station

This is at Humlebaek, about an hour's journey north of Copenhagen. It was set up in 1946, and its function is not research, but to supply the State Forests with seed and plants.

Director Ulrich once again made us welcome, and Kgl. Skovrider F. von Barner, who is in charge of the station, explained that the station acts as a connecting link between forest research and forest practice. Improvement in quality is constantly aimed at and is based largely on the pioneer work of Dr. Larsen, whom we were pleased to have with us. The average annual demand for seed is

about 205,000 lb. of hardwood and 18,600 lb. conifer seed. This is more than can be provided from existing seed orchards, and collection from stands recognized by the Danish Forestry Society's Seed Committee is organized. We followed the various processes from receipt of cones to storage of seed, which were on the usual lines. Seed collection appliances were also shown out of doors. These included a set of pipe ladders, a compressed-air gun, and a tree bicycle.

Luncheon was kindly provided at the Station by the State Forest Service; this was a most enjoyable function, being served in the loft, decorated out of all recognition. Mr. Laurie thanked our hosts, and Skovrider v. Barner replied.

The afternoon was spent seeing clone collections of various species and seed orchards. The latter included one of dioecious ash, where twelve separate clones of female trees were represented, but where all the male trees were grafts from one male tree. Dr. Syrach Larsen was not certain that seed orchards would have the same importance in 10 years' time. Clone cultivation might replace them.

Later we returned to Copenhagen, and in the evening held an informal reception which had two main purposes. One was to make a nominal return, though very inadequate, for the kindness and hospitality with which we had been received everywhere; it was possible to have present only those of our hosts living in or near Copenhagen. The other was, as had been decided by the Council of the Society, to confer on Director Ulrich honorary Fellowship of the Society of Foresters of Great Britain, and this Mr. Long did amid the applause of everyone present. Then, in presenting Kgl. Skovrider Frölund with a memento of the occasion, Sir Harold Glover expressed our very hearty appreciation and thanks to him for the great part he had taken in organizing the programme and in accompanying us throughout as our guide, which contributed so largely towards a very interesting, instructive, and enjoyable tour.

ACKNOWLEDGEMENTS

The Society has many people to thank for the success of the Danish Excursion. It is hoped that most of them will receive this issue of *Forestry*. First and foremost we are indebted to Director Ulrich of the State Forest Service, by whose kind offices the tour was made possible, and to the State Forest Service for hospitality on several occasions. Secondly, to his assistant, Kgl. Skovrider H. Frölund, who made the detailed arrangements, and who conducted the party from first to last. Thirdly, to Kammerherre Iuel and the Danish Forestry Society, who not only were our joint hosts at dinner, but who kindly supplied each excursionist in advance with a copy of *Forestry in Denmark*, an invaluable handbook for visitors. Our thanks are due to Director Thaarup and the Dune Service; to Hofjaegermester Lüttichau and the Danish Heath Society, and its officers Skovrider Steenstrup and Skovrider Bech; to Overförster Lövengreen, Countess Wedell and Count Tido Wedell; to Skovrider Quistgaard, Count J. Wedell and the Wedell Foundation; to Kgl. Skovrider F. Lorenzen and the Principal of Sorö Academy; to Kgl. Skovrider H. von Barner and to Dr. Syrach Larsen; and to many others whom we met and who were always ready to answer our innumerable questions and to make us feel welcome.

THE IMPORTANCE OF SHELTER TO EARLY TREE GROWTH ON UPLAND MOORS

By PETER J. RENNIE

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SUMMARY

A comparison of the effects of differing methods of cultivation carried out on typical *Calluna* moor in the Cleveland (Yorkshire) massif has revealed that single-furrow deep forestry ploughing, by reason of its pronounced plough-ridges, has advantages over other more shallow and complete deep methods of ploughing in giving shelter from cold off-shore winds which cause die-back. Orientation of the plough-ridges transverse to the wind direction and the use of leeward ridge slopes as planting positions enhances this shelter effect. The paper ends by drawing attention to the need for forest meteorological reasearch upon the wind-tree growth relationship.

INTRODUCTION

THE successful afforestation of many nutrient-poor upland *Calluna* moor soils, exemplified by those of the Cleveland (Yorkshire) massif, has been possible by the development of methods of cultivation able to increase survival and growth of transplants by both alleviating certain unfavourable soil properties associated with the uncultivated moor and by temporarily suppressing the natural moor vegetation (7).

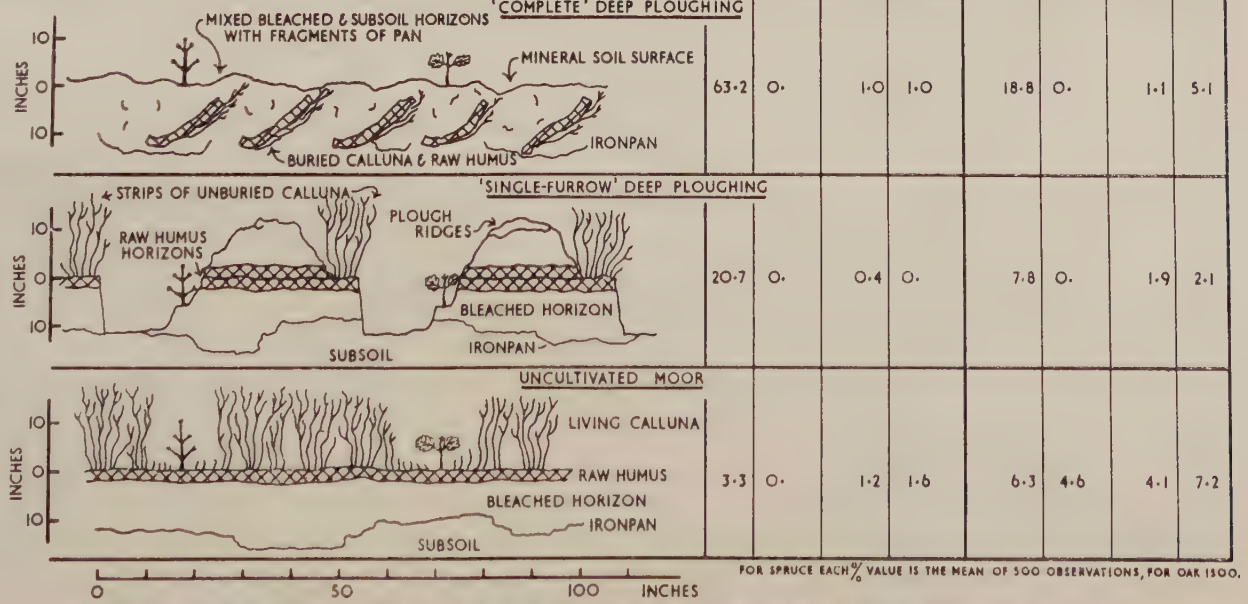
For many of the more commercially desirable species, however, satisfactory growth subsequent to this initial stimulus is possible only so long as the reinvasion of the site by the former moor vegetation is sufficiently retarded for it to be unable to exercise its well-known suppressive effect upon the young trees (9, 13), and factors favouring this retardation are appreciable burial of the moor vegetation by the original cultivation, and for tree growth itself to have progressed so well during the first 5 to 8 years that the shade of the young tree crowns themselves no longer permits a vigorous ground vegetation.

Existing commonly used methods of 'single-furrow' deep forestry ploughing (Fig. 1) have the inherent weakness of leaving unburied and ready for immediate expansion strips of moor vegetation 6 to 12 inches wide, adjacent to the plough-ridges, a weakness which prompted the writer to investigate experimentally within a long-term timber-productivity experiment the comparative value of a type of 'complete' deep forestry ploughing (Fig. 1), which, in addition to providing the usual initial growth-stimulus, was also able to bury entirely all moor vegetation, the available evidence suggesting that such a cultivation might be advantageous by prolonging the period during which tree growth would be free from competing vegetation, thereby shortening the time required for the closing of the canopy.

This investigation has already shown very clearly, however, that under certain characteristically recurring climatic conditions upon upland moors of the British Isles 'single-furrow' deep ploughing provides a very effective and valuable shelter

THE VALUE OF SHELTER TO EARLY TREE GROWTH

CULTURAL TREATMENT	SITKA SPRUCE				SESSILE OAK			
	% DIE-BACKS		% DEATHS		% DIE-BACKS		% DEATHS	
	1952	1953	1952	1953	1952	1953	1952	1953
'COMPLETE' DEEP PLOUGHING	63·2	0·	1·0	1·0	18·8	0·	1·1	5·1
'SINGLE-FURROW' DEEP PLOUGHING	20·7	0·	0·4	0·	7·8	0·	1·9	2·1
UNCULTIVATED MOOR	3·3	0·	1·2	1·6	6·3	4·6	4·1	7·2



FOR SPRUCE EACH % VALUE IS THE MEAN OF 500 OBSERVATIONS, FOR OAK 1500.

NOTES: THE SINGLE-FURROWS RUN LATITUDINALLY WITH THE TREE PLANTING POSITIONS ON THE NORTH SLOPES OF THE PLOUGH-RIDGES. FOR SINGLE FURROW DEEP PLOUGHING AT THE MORE USUAL 5 FT. SPACING THE UNBURIED CALLUNA STRIPS ARE 12 INCHES WIDE.

FIG. 1.

effect to very young trees, not provided by the 'complete', nor by the more shallow ploughing methods.

The purpose of this paper is to demonstrate the importance of this shelter-effect in moor afforestation, and to show how by quite simple modifications to ploughing technique the benefit to tree growth of this shelter-effect may be further enhanced.

CHARACTERISTICS OF THE EXPERIMENTAL SITE

Position: Silpho Moor, Yorkshire.

Physiography: A slightly tilted plateau (slope 1:50) typical of the Tabular Hills, but nearer the sea (5 miles) and of lower altitude (580 feet) than the main Cleveland massif.

Geology: Thick beds of the massive sandstone, Lower Calcareous Grit.

Climate: Mean annual rainfall, 34 inches. The average means of the daily mean temperatures are 37° F. for January and 58° F. for July. Regional wind data (3) show 'gales' (> 8 Beaufort) to be rare, and 'light' breezes (1–3 Beaufort) twice as common as 'strong' breezes (5–6 Beaufort). Over the whole year, on-shore winds (N., NE., E., and SE.), as distinct from off-shore (S., SW., W., and NW.), comprise one-quarter of all 'light' and slightly less than one-half of all 'strong' breezes, but during the January to June half-year these proportions of on-shore winds rise to just under one-third and just over one-half respectively. On-shore 'gales' are only one-third as common as off-shore but winter on-shore winds causing very severe needle browning of Scots pine and blasting of other tree species have been known to occur in 1940, 1947, and 1951. Mature sycamore and ash trees on nearby agricultural land of similar altitude and exposure show no asymmetrical development due to 'wind-cut' (12).

Vegetation: Almost pure *Calluna vulgaris* (mean stem length 18 inches); but with both *Eriophorum* spp., and *Erica tetralix* with *Scirpus caespitosus* locally dominant.

Soil: Podzol with thin hard ironpan. 0–2 inches raw humus, 2–10·9 inches bleached horizon, 10·9–11 inches ironpan, 11–18 inches subsoil, 18 inches+ parent material. This soil has the typical low nutrient-status of other Cleveland moor soils (6) and from a forester's viewpoint is a fair average of the various difficult Cleveland soils available for afforestation.

EXPERIMENTAL TREATMENTS AND ASSESSMENTS

The experimental treatments compared and the assessments carried out are shown in detail in Fig. 1. Briefly, the experiment included three cultural treatments (i) 'complete' deep ploughing, (ii) 'single-furrow' deep ploughing, and (iii) uncultivated control. Randomized 0·12-acre blocks of both 1+1,[1] Sitka spruce (*Picea sitchensis*, Carr) and 1+0,[1] Sessile oak (*Quercus petraea* Liebe) were planted upon all three treatments at 4 ft. 6 in. × 4 ft. 6 in. and 4 ft. 6 in. × 1 ft. 6 in. spacings respectively in March 1952. No manures or fertilizers were applied to

[1] Numbers of years in seedbed and transplant lines respectively in the nursery.

the plots considered here. The percentages of each species both dying entirely and suffering severe die-back (leading and lateral shoots killed) during the first and second growing seasons, i.e. ending October 1952 and October 1953, were assessed. A characteristic damaging on-shore wind, of the type described above, was experienced in the first (April) but not the second growing season.

RESULTS AND DISCUSSION

The assessments show that except for oak upon uncultivated moor, the deaths of both oak and spruce occurring during either the first or second growing season were extremely few upon all treatments and of no practical importance.

Severe die-back, on the other hand, was very different, the more spectacular and significant results being as follows. During the first growing season, the greatest damage to both species occurred on the 'complete' ploughing treatment and the least damage upon the uncultivated moor. Upon both ploughing treatments, however, the percentages of spruce suffering die-back were three times greater than the oak, and the damage to the spruce upon 'complete' ploughing was so extensive that 2 out of every 3 transplants were affected. Upon the 'single-furrow' ploughing 1 out of every 5 spruce and very few oak were affected. During the second growing season, except for oak upon uncultivated moor, there was no fresh die-back upon any treatment, a result similar to that recorded elsewhere on this moor during the first growing season when cold on-shore winds were not experienced (7).

Local microclimatic wind data were not available, but wind studies carried out elsewhere upon soil surfaces similar aerodynamically to those of this investigation suggest the differences in die-back among the three cultural treatments to be determined in the first instance by variation in exposure to high-velocity wind. Thus, wind-speed decreases very rapidly as surfaces are approached, but the rate of decrease near the surface depends very much on the 'roughness' or so called 'macroviscosity' of the surface (11), comparative studies of W. Paeschke (4, 5) showing this rate to be least for 'smooth' surfaces such as snow cover or agricultural fallow soil and greatest for 'rough' surfaces such as bracken or a tall wheat-field.

It is reasonable to suppose, therefore, that wind-speed and 'run-of-miles' of wind passing the tree transplants during a gale would be very considerably greater for those on the 'smooth' soil surface left by 'complete' ploughing than for those nestling among the 18-inch tall *Calluna* of the uncultivated moor, and partial confirmation of this is shown by the observation (10) that although during a gale the wind-speed may be as high as 21 m.p.h. only 6 feet above a *Calluna* moor, just above the 20-inch tall *Calluna* it is only 8·3 m.p.h. and among the *Calluna* stems 4 to 12 inches from the ground as low as from 2·2 to 3·1 m.p.h.

The ridges left by 'single-furrow' ploughing offer less protection to the tree-planting positions (on the north slopes) than uncultivated *Calluna*, but markedly greater protection than the 'smooth' 'completely' ploughed surface. Although no wind-data for this particular type of 'single-furrow' ploughing are available, some explanation of this result is provided by a comparative study of wheat and

beans on a level surface and potatoes upon ridged soil (1), the percentage reduction in wind-speed within the crop foliage being greatest for the potatoes upon the ridged soil, particularly at greater external wind velocities.

Data additional to those available here would be required to show whether die-back were due to cold wind alone, or to a combination of cold wind and salt-spray, which can on occasions be carried many miles inland (12). From the natural distribution of Sitka spruce, neither cold wind nor salt-spray would be expected separately to cause the die-back recorded, but the greater die-back suffered by spruce compared with oak does suggest, partly because of the lesser dormancy of the spruce and the greater frost susceptibility of species at this stage of development and partly because the taller spruce transplants (8 against 4 inches) were in an aerial environment of greater mean wind-speed, that cold wind alone could be an important contributory cause. On the other hand, cold winds perhaps of less intensity but without accompanying browning of *Pinus sylvestris* needles (a good criterion of the presence of salt spray) neither caused die-back upon the spruce here during its second growing season nor upon spruce nearby on comparable treatments during its first growing season.

But some further insight into the complex physiology of die-back is shown by the observation that the percentage die-back of both species was slightly less upon a comparable set of treatments which had all received an initial application of limestone.

In afforestation practice, the considerable shelter shown to be afforded by the living *Calluna* of an uncultivated moor can rarely be utilized, for few species are able to grow under such conditions, and cultivation prior to planting is now very widely practised.

For localities where, by reason of slope or boulders, cultivation is impossible, however, a valuable shelter-effect for the first few seasons' tree growth can be preserved by not burning the *Calluna*, although some form of patch hand-cultivation and planting might need to be developed to restrict the suppressive effect to tree growth of the vigorous *Calluna*.

Clearly, the planting positions provided by 'complete' ploughing are of little value, for if cold on-shore winds cause severe die-back during any one of the early growing seasons tree growth is so greatly retarded that any advantage that might have resulted from the increased burial of the moor vegetation, compared with 'single-furrow' ploughing, would be more than offset by the time taken for growth to make up for the die-back suffered.

Regarding 'single-furrow' deep ploughing, the cultivation commonly used in moor afforestation today, it is clear that some part of its greater stimulus to early tree growth, compared with the shallower types of ploughing used before 1939, and in particular the very shallow ploughing with prior burning of the *Calluna* in use before 1930, must be due to the greater shelter it provides, but the question that now arises is whether the value of this shelter has been sufficiently appreciated for plough-ridges to be orientated and planting positions chosen in present-day afforestation practice to exploit this shelter-effect to the full, for quite aside from the obvious desirability of getting the best possible early tree growth is the need

to avoid unnecessary expenditure upon plant-replacement and hand-weeding which are both required if tree growth is impaired. Thus, within this same forest experiment, although during the first growing season die-back upon spruce planted on the north slopes of plough-ridges was 20·7 per cent., for ridges with south-facing planting positions (not shown in Fig. 1) it assumed the negligibly low proportion of 2·3 per cent.

In this locality, therefore, it seems probable that the utilization of plough-ridges transverse to the prevalent direction of cold on-shore winds and planting positions on the lee or south slopes of these ridges could almost entirely eliminate die-back upon early tree growth caused by these winds. Furthermore, because the frequency of 'gales' for most other upland moors of the British Isles (2) is markedly greater than in this locality, the exploitation of the maximum shelter-effect of the plough-ridges might for moor afforestation generally merit even greater attention by reason of its even greater importance to early tree growth.

For particular moors, however, the realization of this maximum-shelter effect necessitates two preliminary developments. Firstly, the most advantageous plough-ridge orientation and planting position must be elucidated by experimentation continued long enough to include potentially damaging climatic spells, particular care being taken to differentiate climatically and edaphically most favoured conditions. Secondly, modification to the existing 'single-furrow' forestry plough or ploughing is required to enable both sides of the furrow-slice to be readily utilized as planting position, for only by such a modification can all trees be planted on the more favourable side of the plough-ridge. Reduction of the ploughing spacing to 4 feet and the development of an inclined coulter wheel is a possible solution.

CONCLUSION

Cold on-shore winds able to cause severe die-back of very young trees appear to be an important climatic characteristic which occurs every few years upon inland upland moor soils of the Cleveland (Yorkshire) massif.

During such winds, the die-back suffered by spruce and oak transplants upon *Calluna* moor cultivated in three different ways was inversely related to the reduction in wind-speed or shelter which, from other theoretical studies, each type of cultivation would be expected to produce in the immediate environment of the transplants.

The greater proportion of die-back suffered by spruce compared with oak suggested that die-back was due to a combination of cold wind and salt-spray, but low soil-nutrient status appeared also to be a small contributory factor.

In moor afforestation, the seriousness of die-back lies partly in its retardation of tree growth, which gives reinvading competing vegetation one or more growing seasons' advantage, and partly in the extra expenditure incurred through plant-replacement and hand-weeding. The existing widely used method of 'single-furrow' deep forestry ploughing provides, by reason of its pronounced plough-ridges, tree-planting positions far more protected compared with both many earlier more shallow ploughing methods and certain more edaphically favourable

present-day experimental methods, such as 'complete' deep ploughing. This greater protection is considered to account for part of the greater stimulus to early tree growth of 'single-furrow' deep compared with other methods of ploughing.

Because the data show that die-back upon both spruce and oak can be almost entirely eliminated when the plough-ridges are orientated approximately transverse to the direction of the cold on-shore wind and planting positions utilized on the south or lee slopes of the ridges, it is clear that existing afforestation practice upon the Cleveland massif and upon the many other more exposed upland moors of the British Isles, by ploughing in no particular direction, does not exploit this potential shelter-effect of 'single furrow' ploughing to the fullest advantage to tree growth.

Although simple modifications to 'single-furrow' ploughing technique are suggested to obtain this maximum shelter-effect, the greater forestry need in this country today is seen to be forest meteorological research upon the wind–tree growth relationship.

ACKNOWLEDGEMENTS

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AN ENUMERATION OF THE MATURE OAK IN THE FOREST OF BERE

By D. R. JOHNSTON

(*Forestry Commission*)

SUMMARY

The paper describes the methods used in the field and in the office to determine the standing volumes and increments of 100- and 130-year old oak in the Forest of Bere, Hampshire, during working-plan revision. The figures obtained show that the standing volumes and increments of sessile oak (*Quercus petraea* Liebe) are considerably higher than those of pedunculate oak (*Q. robur* L.) on the three sites investigated, namely, clays, sands, and gravels, while for both species sands appear to be the most favourable and gravels the least favourable soil types. There was little difference in the mean values for increment and standing volume between the 100- and the 130-year old pedunculate oak.

INTRODUCTION

IN the course of revising the working plan for the Forest of Bere, the standing volumes and increments of the 721 acres of mature oak were investigated. This paper describes the methods used in the field and in the office and discusses briefly the results obtained.

The Forest of Bere originally occupied a large area in south-east Hampshire stretching from Southampton in the west to Havant in the east. The north and south boundaries were marked by outcrops of chalk and the forest lay in the synclinal trough occupied by Tertiary deposits consisting largely of Reading Clay, London Clay, and Bagshot Sands. More recent deposits of gravel are largely confined to high ground. Today the area of forest has shrunk very considerably and the Forestry Commission owns two blocks known as West Walk and Creech Walk. The former occupies 902 acres and the latter 548 acres. The mature oak under investigation was planted with conifer nurses in two periods; the first between 1820 and 1830 and the second between 1850 and 1860. When the working plan was due for revision in 1955 the condition of the older oak had become a matter of some concern and it appeared probable that a policy of gradual replacement would be necessary.

The object of this investigation was to obtain estimates of the standing volumes and current annual increments of the 100- and 130-year old oak by 'crop types', compartments, and sub-compartments. The expression 'sub-compartment' is used here to mean a forest stand which may be distinguished from adjoining stands by a difference in specific composition, age, or soil. The information obtained from the investigation was used in the revision of the working plan.

METHOD

Choice of method. The increment of a stand may be estimated either by comparing it with other stands for which the results are known (e.g. by the use of yield tables) or by measurements taken within the forest itself. There are, broadly speaking, two methods of estimating the increment by measurements within the forest. The one consists in measuring the crop twice with a relatively long interval of time between each enumeration. The other method consists in using increment cores, and does not entail this delay, but requires a reasonably uniform type of forest. In both methods the results obtained refer only to the actual growth for

the period (usually 10 years) immediately prior to sampling. This growth depends upon site and treatment. Therefore, comparison between different species or sites is only possible if past treatment has been similar over the areas to be compared. As conditions were satisfied at Bere and since the information was wanted as soon as possible, a method based upon increment borings was adopted. As a preliminary, a stock map, soil map, and 'crop-type' map were prepared and each crop type was then sampled separately.

Stock map. According to documentary evidence the mature oak was planted in two periods, 1820–30 and 1850–60. For simplicity, two age classes were recognized, and are referred to as 130-year old oak and 100-year old oak respectively. It was known that the 100-year old age class consisted of both sessile and pedunculate oak but the 130-year old oak was believed to be all pedunculate. In fact one small area was found in which the crop appeared predominantly sessile in appearance. Samples from 6 trees were examined by the geneticist at the Forestry Commission Research Station and he considered 3 to be sessile, 2 to be pedunculate, and 1 to be indeterminate. All the oak stands were examined to determine their species and age and they were plotted on a 6 inch to the mile outline map (Scale 1 : 10560).

Soil map. No geological survey drift maps were available, so a soil map was prepared from soil pits and borings. Six soil types were recognized, namely:

1. Heavy loams and clays (derived from Reading Beds and London Clay).
2. Light loams (derived from Bagshot Sands).
3. Sands (derived from Bagshot Sands).
4. Gravelly sand (probably Pleistocene deposits over sand occurring on high ground only).
5. Gravelly clay (probably Pleistocene deposits over clay occurring on high ground only).
6. Gravelly loam over clay (a transported soil in a river valley).

These were marked as accurately as possible on an outline 6 inch to the mile map for future silvicultural use, but for the purpose of the enumeration this soil map was somewhat simplified. Three principal soil types only were recognized—sands, clays, and gravels—and their boundaries were as far as possible made to coincide with compartment boundaries. Owing to the shallow angle of dip of the geological horizons there is considerable intermixing of one parent soil material with another. For this reason no great sacrifice of accuracy was entailed in making the soil boundaries on the map coincide with compartment boundaries.

'Crop-type' map. By superimposing the stock map on to the simplified soil map a 'crop-type' map was obtained, giving eight crop types, i.e.

1. 130-year old pedunculate oak on clay.
2. 130-year old pedunculate oak on sand.
3. 130-year old pedunculate oak on gravel.
4. 100-year old pedunculate oak on clay.
5. 100-year old pedunculate oak on gravel.
6. 100-year old sessile oak on clay.
7. 100-year old sessile oak on sand.
8. 100-year old sessile oak on gravel.

Each crop type within a compartment was designated a sub-compartment and given a sub-compartment letter on the crop-type map.

Sampling technique. As near as possible 10 per cent. by area of each crop type was sampled in $\frac{1}{2}$-acre sample plots. The sampling was systematic, the samples

being laid out on a predetermined grid with the aid of a prismatic compass. Plots were demarcated at exactly regular intervals along the grid lines and rides were accepted in the plots wherever they occurred in the strict sampling pattern. Within the plots every tree was girthed to the nearest 1 inch quarter girth and every fifth tree was bored with a Pressler borer and its timber height measured with a Christen's hypsometer, timber height being defined as the point on the stem where the overbark diameter is 6 inches or where the main axis of the stem loses itself in the crown below that point. Borings were taken round the compass, i.e. north, east, south, and west in rotation, the radial length at breast height in inches of the last ten annual rings being recorded. Before measuring was started ivy was removed from all the trees in the plot, a soil pit was dug, and the plot assessed for crown vigour. This last assessment was done subjectively by allocating the plot as a whole to one of five arbitary crown classes ranging from (1) vigorous and healthy to (5) dying. The object of this assessment was to assist in the compilation of a clear-felling schedule. The subjective and arbitrary nature of the method of assessment to crown classes renders the result of moderate value only.

Summaries of sample plot data. Each crop type was treated as a separate unit and the data from all the sample plots within each crop type were summarized under the following headings.

1. Total number of trees by 1 inch quarter girth classes. (This information was also summarized for each sub-compartment and compartment in order to calculate their individual standing volumes.)
2. Height/girth curve (for the preparation of local crop-type volume tables).
3. Underbark radial increment/quarter girth breast height (q.g.b.h.) curves. The points on these graphs were found to have a wide scatter. The calculated linear regressions through these points are shown in Fig. 1*a*, *b*, and *c*.

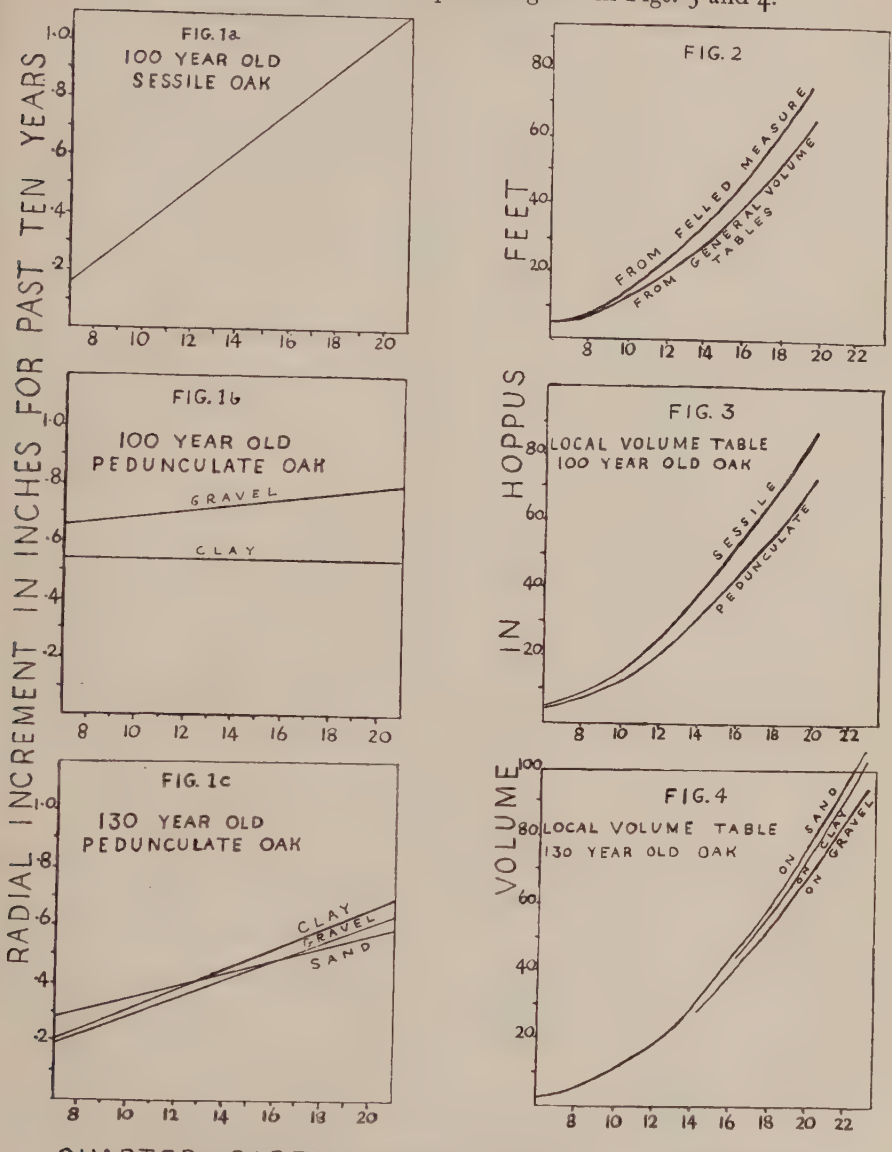
   The standing volume of each compartment and sub-compartment was calculated separately but the volume increment per cent. was only calculated for each crop type as a whole.

By applying the increment per cent. of the appropriate crop type to the actual standing volume in each compartment and sub-compartment, estimates of the volume increments per acre were obtained.

Construction of local volume tables. In order to use the interpolation method of calculating the increment, it was necessary to have reliable volume tables. It was suspected that the general volume tables for oak (3) were not strictly applicable to the stands under investigation. Eighty felled trees were chosen randomly throughout the forest and their measured volumes compared with those obtained by applying the general volume tables of the Forestry Commission to the same trees. It appeared that up to a q.g.b.h. of 11 inches (and a timber height of 20 feet) the general volume tables underestimated the volumes by about 10 per cent. and over 15 inches q.g.b.h. (or a timber height of 40 feet) the volume tables under read by about 20 per cent. This relationship is illustrated in Fig. 2. Accordingly local volume tables were prepared for each crop type and used instead.

Height/girth curves were drawn for each crop type and with the aid of these, volume/q.g.b.h. curves were constructed from general volume tables with appro-

priate allowances made for the underestimates of volume in this locality given by the general volume tables. Two examples are given in Figs. 3 and 4.



FIGS. 1 to 4.

Calculation of increments. The increments were calculated by an interpolation method similar to that described by H. A. Meyer (4). The steps in the calculation are illustrated in Table I and are described in the notes on page 159.

Summary of results. Summaries of areas, volumes, and increments for the two sections of the Forest of Bere and summaries by crop types are given in Table II.

TABLE I. *Example of increment calculation*

Forest of Bere: West Walk. Area of sample: 3 acres. Volume per acre: 1,853 cu. ft. Total increment of crop type: 793 cu. ft.
Crop type: 90–100-year old pedunculate oak on clay. Total area crop type: 31 acres. Total volume of crop type: 57,430 cu. ft. Increment %: 1·38.

Girth class (inches q.g.) 1	*Vol. per tree (b. ft.)* 2	*Vol. diff. betw. 1″ girth classes (b. ft.)* 3	*Vol. incr. per 1″ girth incr. (b. ft.)* 4	*Underbark diam. incr. per year (inches)* 5	*o.b. diam. incr. per year (inches)* 6	*o.b.q.g. incr. per year (inches)* 7	*Vol. incr. per year (b. ft.)* 8	*Vol. incr. %* 9	*No. trees in girth class* 10	*Total vol. of class (b. ft.)* 11	*Total incr. of class (b. ft.)* 12
				Radial incr. per 10 years × 2 ÷ 10	col. 5 × 1·075	col. 6 × 3·142/4 i.e. o.b. diam. inc. × π/4	col. 7 × col. 4	col. 8/col. 2 × 100	From field notes	col. 2 × col. 10	col. 11 × col. 9
7	4·6		2·0	0·104	0·1118	0·0878	0·176	3·82	1	4·6	0·18
		2·2									
8	6·8		2·5	0·1042	0·1120	0·0879	0·220	3·23	4	27·2	0·88
		2·8									
9	9·6		2·95	0·1044	0·1122	0·0881	0·260	2·71	10	96·0	2·60
		3·1									
10 &c.	12·7		3·3	0·1046	0·1125	0·0082	0·291	2·29	16	203·2	4·66

Notes to Table I

1. The range of girth classes recorded in the field is set out in col. 1.

2. The volume per tree in each 1 inch q.g. class is obtained from the appropriate local volume table and recorded in col. 2.

3. The volume differences between successive 1 inch q.g. classes are found by subtraction from the values in col. 2 and recorded in col. 3.

4. By taking the means of each successive pair of figures of col. 3, a value is obtained which represents the volume put on by a tree in passing through a girth class, e.g. in passing through the 8 inch q.g. class the tree increases in q.g. from $7\frac{1}{2}$ to $8\frac{1}{2}$ inches and increases in volume by 2·5 hoppus feet. These volume increments are entered in col. 4.

5. In col. 5 are entered the average underbark diameter increments per tree as derived from the radial increments in Fig. 1.

6. The underbark increment has to be converted to an overbark increment in order to utilize volume table figures and to bring the results into line with normal volume measurements. Dr. Hummel (personal communication) has found by experience that in oak an acceptable result is obtained if the underbark diameter increment is multiplied by 1·075 in order to obtain the overbark diameter increment. This was done in order to avoid the troublesome business of measuring bark thickness as well as underbark diameter increment in the sample plots. The result is entered in col. 6.

7. Having obtained for each girth class a mean value for the overbark diameter increment it is necessary to convert this into an overbark quarter girth increment (again so that volume table figures may be utilized). Col. 7 shows the results of this conversion:

$$\text{Overbark diameter increment} \times \pi/4 = \text{Overbark quarter girth increment per year.}$$

8. In practice since the conversion factor for underbark to overbark diameter increment is taken to be a constant, steps (6) and (7) may be combined and col. 6 in the table omitted. We have found the volume increment per 1 inch girth increment from volume tables (col. 4) and we now have the actual o.b.q.g. increments of each girth class (col. 7) therefore the overbark q.g. increment is easily converted into a volume increment (col. 7 × col. 4) and this is recorded in col. 8.

9. The volume increment per year for each girth class may be expressed as a percentage of the actual volume of that class to give the volume increment per cent.

$$\text{i.e. } \frac{\text{col. 8 (vol. increment per year)}}{\text{col. 2 (vol. of girth class)}} \times 100.$$

10. From the sample plot summaries the number of trees in each girth class is recorded in col. 10.

11. The volume of each girth class (taken from volume tables) is multiplied by the number of trees in that girth class (taken from the sample plot summary) to give the total volume of the class: col. 11.

12. The total increment of each girth class is found by multiplying the volume of the class by its increment per cent.

TABLE II. *Summary of results*

Volumes and increments by crop types

1. *Final summary of area, volume, and increment for the two sections of the Forest of Bere*

	Area	*Total vol.*	*Total incr.*	*Incr. %*	*Incr./acre/annum*
(*a*) *West Walk*	505·5 ac.	944,890 h. ft.	12,959 h. ft.	1·38	25·6
(*b*) *Creech* .	215·5 „	438,310 „	5,655 „	1·29	26·2
	721·0 „	1,383,200 „	18,614 „	..	25·8

2. *Summary by crop types*

	Area	*Vol./ acre*	*Total vol.*	*Total incr.*	*Incr. %*	*Incr./acre/ annum*
a) West Walk						
130-yr. old pedunculate oak:						
on clay	252	1,837	462,910	6,253	1·35	24·8
on sand	144	1,957	281,990	3,552	1·26	24·7
on gravel	37·5	1,682	63,060	777	1·23	20·7
	433·5	..	807,960	10,582	..	..
100-yr. old pedunculate oak:						
on clay	31	1,853	57,430	793	1·38	25·6
on gravel	10·5	1,175	12,340	327	2·65	31·0
	41·5	..	69,770	1,120	..	..
100-yr. old sessile oak:						
on clay	17	2,092	35,560	674	1·91	40·0
on sand	10	2,352	23,520	434	1·84	43·3
on gravel . . .	3·5	2,307	8,080	149	1·85	42·7
	30·5	..	67,160	1,257	..	..
Total. . . .	505·5	..	944,890	12,959	..	..
(*b*) *Creech*						
130-yr. old pedunculate oak:						
on clay	92·5	1,947	184,980	2,320	1·25	24·3
on sand	115·0	2,067	238,720	3,117	1·31	27·0
	207·5	..	423,700	5,437	..	..
100-yr. old pedunculate oak on clay	6·7	1,716	11,500	158	1·38	23·7
100-yr. old sessile oak on clay .	1·3	2,395	3,110	60	1·92	46·0
	8·0	..	14,610	218	..	..
Total. . . .	215·5	..	438,310	5,655	..	..
Grand Total . .	721 acres	..	1,383,200	18,614	..	..

RESULTS AND DISCUSSION

Comparison between West Walk and Creech Walk. Table III shows that the differences between the two inclosures are small and probably have no significance. They might easily be explained by slight differences in treatment.

TABLE III. *Comparison between West Walk and Creech Walk*

	West Walk		*Creech*	
	Vol. b. ft.	*Incr. %*	*Vol. b. ft.*	*Incr. %*
130-yr. old oak on clay	1,837	1·35	1,947	1·25
130-yr. old oak on sand	1,957	1·26	2,067	1·31
100-yr. old pedunculate oak on clay . .	1,853	1·38	1,716	1·38
100-yr. old sessile oak on clay . . .	2,092	1·91	2,395	1·92

Comparison between pedunculate oak and sessile oak. The most striking result is the pronounced superiority of the sessile oak in stocking and increment on all sites. This is shown in Table IV. Compared with pedunculate oak of the same age, the periodic mean annual increment per acre is more than 50 per cent. higher on corresponding sites, while the standing volume is 16 per cent. greater on the clay and almost 100 per cent. higher on the gravel.

TABLE IV. *Comparison between pedunculate oak and sessile oak*

	Clay		*Sand*		*Gravel*	
	p.m.a.i. (b. ft./acre)	*Vol./acre (b. ft.)*	*p.m.a.i. (b. ft./acre)*	*Vol./acre (b. ft.)*	*p.m.a.i. (b. ft./acre)*	*Vol./acre (b. ft.)*
Sessile oak, 100 years old	40	2,113	43·3	2,352	42·7	2,307
Pedunculate oak, 100 years old	25·2	1,830	..	..	31·0	1,175

Sessile oak is more shade bearing than pedunculate and for that reason habitually carries a greater volume per acre. It is also relatively immune to the ravages of the oak roller moth (*Tortrix viridana*) which has caused serious damage to the pedunculate oak at Bere on a number of occasions. Professor Anderson, amongst others (verbal communication and (1)), is of the opinion that sessile oak is indigenous to the south of England and may originally have been more widespread than pedunculate oak. In this connexion it is of interest to note that there is in the forest one sessile oak which must be at least 500 years old.

The relationship between 100-year old sessile oak and site. An inspection of Table V and Fig. 5 shows very little difference between the performance of sessile oak on sand and gravel. The standing volumes and increments and their distribution by girth classes are very similar, whereas on the clay the standing volume and increments are somewhat lower. It would, however, be unwise to deduce much from these figures regarding the varying suitability of sand, clay, and gravel for the growth of sessile oak. The samples were relatively small and the

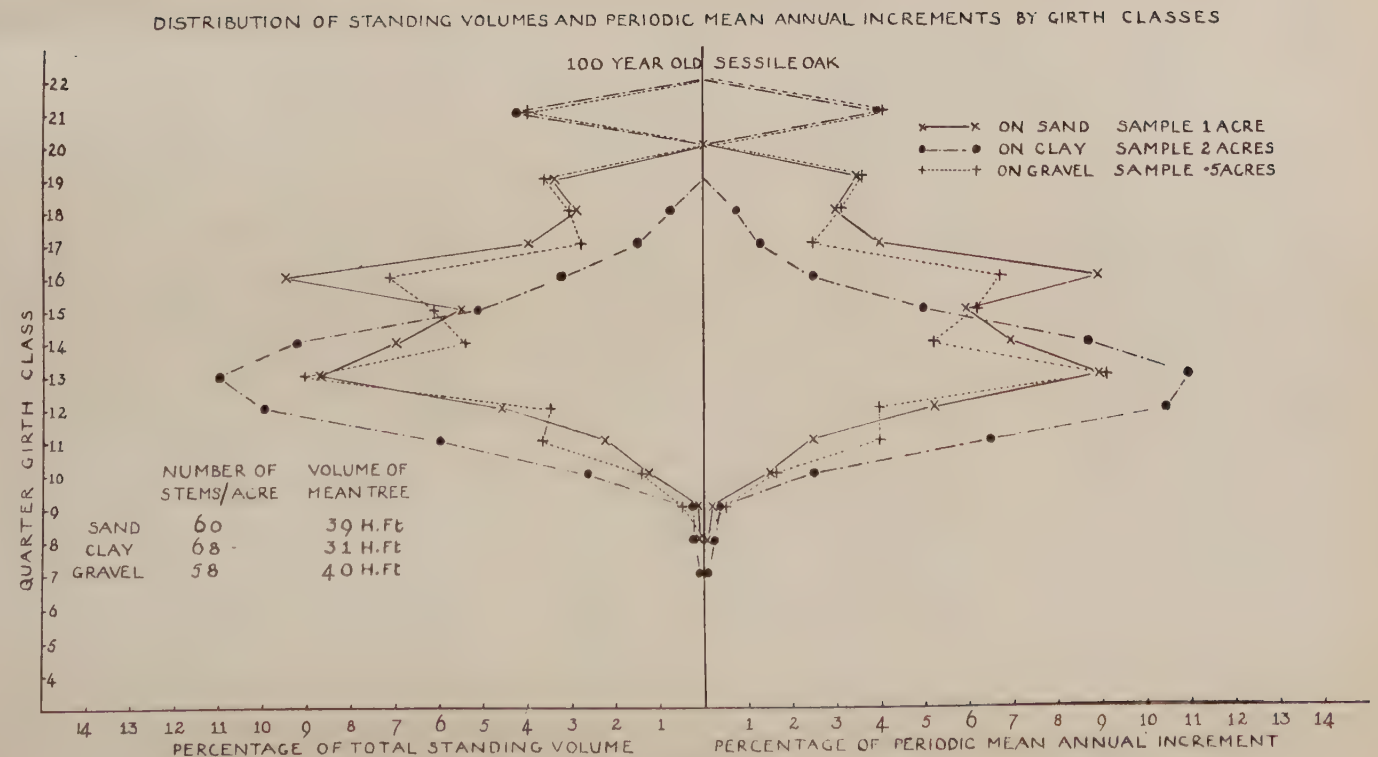

DISTRIBUTION OF STANDING VOLUMES AND PERIODIC MEAN ANNUAL INCREMENTS BY GIRTH CLASSES
100 YEAR OLD SESSILE OAK
ON SAND SAMPLE 1 ACRE
ON CLAY SAMPLE 2 ACRES
ON GRAVEL SAMPLE .5 ACRES
QUARTER GIRTH CLASS
NUMBER OF STEMS/ACRE
VOLUME OF MEAN TREE
SAND 60 39 H.Ft
CLAY 68 31 H.Ft
GRAVEL 58 40 H.Ft
PERCENTAGE OF TOTAL STANDING VOLUME
PERCENTAGE OF PERIODIC MEAN ANNUAL INCREMENT

FIG. 5.

Fig 5.

differentiation between clays and gravels somewhat arbitrary. There is in fact a continuous gradation from gravel through gravelly clay to clay. Some of the areas demarcated as gravel contain a considerable loamy fraction.

TABLE V. *Relationship between sessile oak and site*

	Vol./acre (b. ft.)	*Incr./acre/annum (b. ft.)*	*Stems/acre*
Sand . .	2,352	43·3	60
Clay . .	2,113	40·0	68
Gravel . .	2,307	42·7	58

The relationship between 100-year old pedunculate oak and site. The results for the 100-year old pedunculate oak on gravel appear, from an inspection of Table VI and Fig. 6, to be somewhat anomalous.

TABLE VI. *Relationship between 100-year old pedunculate oak and site*

	Vol./acre (b. ft.)	*Incr./acre/annum (b. ft.)*	*Stems/acre*
Clay . .	1,853	25·6	50
Gravel . .	1,175	31·0	61

The clue to the high increment on the gravel probably lies in the very low volume, the distribution of which differs markedly from that of the same species on clay (Fig. 6). The stand from which two of the three sample plots were taken was thinned heavily 4 years ago and the trees have almost free crowns. An examination of the borings suggests that the trees began to respond to the thinning after 3 years. A high rate of increment for the last 2 years is, however, insufficient to account for a high periodic mean annual increment taken over 10 years. Fig. 6 rather suggests that some sort of selective felling has taken place on the gravel because the concentration of stems in the lower girth classes seems to be incompatible with a high increment rate, but I cannot find any evidence to support this belief. In any case too much emphasis should not be placed upon the soil type, because here again the few sample plots were taken from marginal sites where the gravel contains a relatively large heavy loam fraction which may well combine the fertility of the clay with the better drainage of the gravel.

The relationship between 130-year old pedunculate oak and site. Table VII and Fig. 7 indicate the distribution of standing volumes and periodic mean annual

TABLE VII

	Vol./acre (b. ft.)	*Incr./acre/annum (b. ft.)*	*Stems/acre*
Sand . .	2,010	25·7	40
Clay . .	1,880	24·9	43
Gravel . .	1,682	20·7	45

DISTRIBUTION OF STANDING VOLUMES AND PERIODIC MEAN ANNUAL INCREMENTS BY GIRTH CLASSES

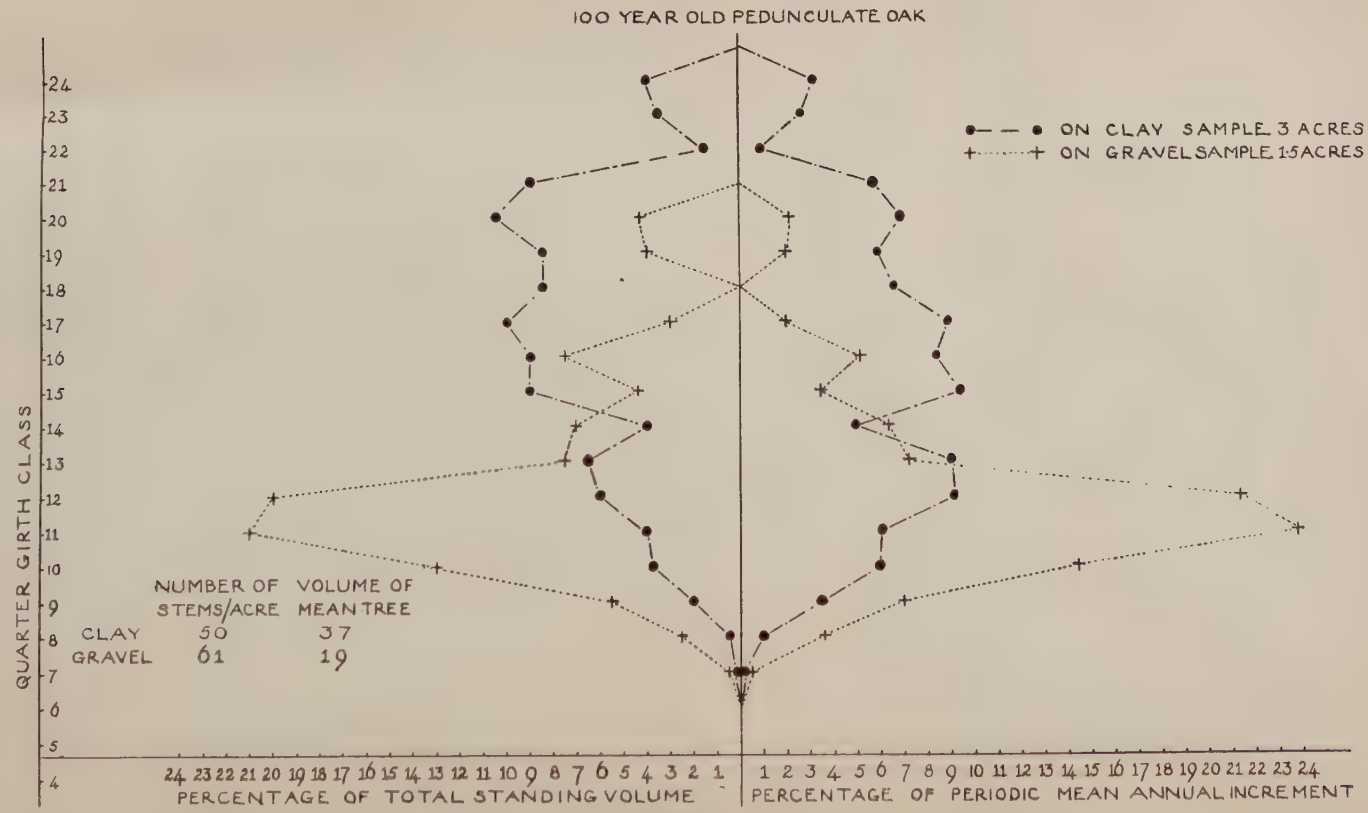

100 YEAR OLD PEDUNCULATE OAK
ON CLAY SAMPLE 3 ACRES
ON GRAVEL SAMPLE 1·5 ACRES
QUARTER GIRTH CLASS
NUMBER OF STEMS/ACRE
VOLUME OF MEAN TREE
CLAY 50 37
GRAVEL 61 19
PERCENTAGE OF TOTAL STANDING VOLUME
PERCENTAGE OF PERIODIC MEAN ANNUAL INCREMENT

FIG. 6.

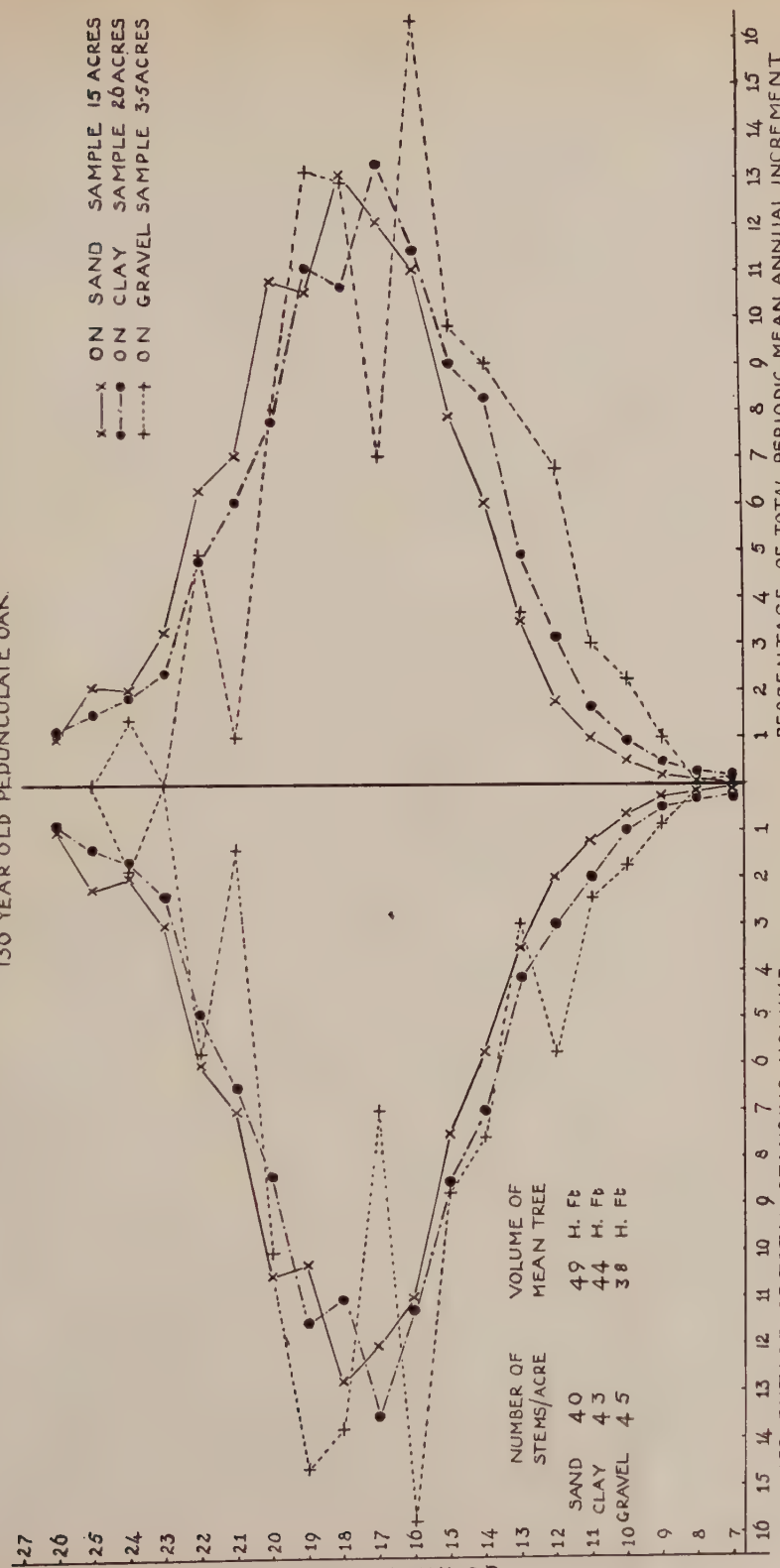

DISTRIBUTION OF STANDING VOLUMES AND PERIODIC MEAN ANNUAL INCREMENTS BY GIRTH CLASSES
130 YEAR OLD PEDUNCULATE OAK
ON SAND SAMPLE 15 ACRES
ON CLAY SAMPLE 26 ACRES
ON GRAVEL SAMPLE 35 ACRES
QUARTER GIRTH CLASS
PERCENTAGE OF TOTAL STANDING VOLUME
PERCENTAGE OF TOTAL PERIODIC MEAN ANNUAL INCREMENT
NUMBER OF STEMS/ACRE
VOLUME OF MEAN TREE
SAND 40 49 H. Ft
CLAY 43 44 H. Ft
GRAVEL 45 38 H. Ft

Fig. 7.

increments by girth classes for 130-year old oak on each soil type. The larger samples in this case enable more significance to be attached to the results than was possible with the 100-year old oak.

Although the top heights of the crops were not determined it appears that the sand is the most favourable site and the gravel the least favourable. The number of trees per acre is least on the sand and greatest on the gravel while the volume of the mean tree is least on the gravel and greatest on the sand. It is worth noting in passing that this sand which maintains a good quality mull soil under an oak crop will probably tend to the formation of a raw humus with attendant podzolization under a pure conifer crop. The variations in the distribution of volumes and increments between girth classes is clearly demonstrated by the graph which shows a concentration of increment and volume towards the higher girth classes in the case of those trees growing on sand and a concentration towards the low girth classes in the case of those growing on gravel. The greater departure from a normal distribution curve in crops on the gravel is due to the smaller sampling area.

There is in general a relatively sparse shrub and herb layer and the crowns of the trees before thinning occupy fully the available canopy space. Throughout most of the forest the site is thus exploited with at least moderate intensity and it would appear that the volumes of 1,905 h. ft. per acre with a p.m.a.i. of 25·1 h. ft. per acre in the case of pedunculate oak and 2,210 h. ft. per acre with a p.m.a.i. of 41·4 h. ft. in the case of sessile oak represents something approaching the true capability of the forest, although a different thinning régime might have increased the proportion of measurable timber to cordwood.

The relationship between the 100- and 130-year old pedunculate oak—Length of rotation. Table VIII shows that there is no great difference between the standing volumes and increments per acre of the older and younger pedunculate oak. The mean standing volume per acre of the 100-year old oak is 1,686 h. ft. This average volume includes the somewhat atypical figures from the gravel plots mentioned above which tend to exaggerate the contrast between the two age classes.

TABLE VIII. *Relationship between the 100- and 130-year old pedunculate oak*

	130-yr. old oak	*100-yr. old oak*
Radial width of last 10 annual rings (inches):		
10 inch q.g. tree	0·302	0·602
20 inch q.g. tree	0·629	0·652
Mean standing vol./acre (h. ft.)	1,921	1,686
Mean annual incr./acre (h. ft.)	25	26·5
Av. no. trees/acre	42	54

There is, however, a considerable difference between the two age classes in the ring width/q.g.b.h. relationship. The ring width of the 130-year old pedunculate increases relatively steeply with increase in quarter girth, whereas that of the 100-year old pedunculate oak varies rather less with girth. In both age-groups the dominants are producing about 15 rings to the inch. The relatively steep

positive slope of the ring width/q.g.b.h. curve in the case of the 130-year old oak suggests a crop differentiated into moderately large crowned dominants and smaller suppressed and deteriorating trees, and this suggestion is confirmed by observation.

The very much more gradual variation of ring width with girth in the younger pedunculate stands suggests a less sharply differentiated crop with less evidence of suppression and deterioration and again observation tends to confirm this suggestion.

Although the 130-year old dominants have ample crown space their ring width is slightly less than that of 100-year old trees of comparable size, in spite of the fact that the younger trees, owing to the more uniform nature of the crop and the greater number of stems per acre, are probably experiencing a greater degree of competition. Therefore it appears possible that the growth potential of the oak may have declined between the ages of 100 and 130 years. During the period of vigorous growth of a tree crop, ring width is approximately inversely proportional to bole area (Hiley and Lehtpere (2)), and during this period, ring width, within the capabilities of the site, may be controlled by the intensity of thinning. There comes a time, however, when the cambial vigour diminishes and ring width decreases no matter how heavily the crop is thinned. The present growth rate of the dominants which are producing about 15 rings to the inch is very small in relation to the standing volume and hence to the capital it represents. It would appear that this ring width could be increased in the 100-year old stands, although to what extent is problematical, but it is doubtful if the 130-year old dominants would respond to any appreciable extent to a silvicultural thinning. The desirable rotation of pedunculate oak at Bere Forest is therefore likely to be less than 130 years and may well be no more than 100 years. It is doubtful, however, if pedunculate oak should ever be grown on a site where the dominant trees at 95 years of age are producing 15 rings to the inch and the crop as a whole 26·5 h. ft. per acre per annum. The sacrifice in potential increment compared with other species, which could be grown on the site, is too great. The ring width could no doubt be increased by adopting a different thinning technique but it seems very doubtful whether it could ever be increased sufficiently to produce 6–8 rings to the inch—a growth rate generally considered to be economically desirable.

Sessile oak is represented by only one age class; it is therefore not possible to make any deductions as to the possible length of a suitable rotation from the data available. The radial increment increases relatively steeply with increase in girth, due possibly to the heavier stocking and greater shade-bearing capacity of this species as compared with pedunculate oak. The smaller trees remain healthy but put on relatively little increment compared with the larger crowned dominants. Sessile oak dominants at 100 years of age are now producing about 10 rings to the inch. It is reasonable to suppose, had large crowns been developed at an early age and relatively free growth been permitted, that a growth rate of about 8 rings to the inch could have been maintained for 100 years, producing trees having a b.h.q.g. of about 18 inches at 80 years or about 22·5 inches at 100 years.

ACKNOWLEDGEMENTS

The author is indebted to Mr. R. H. Smith, Conservator South East England, for permission to undertake the work, to Mr. R. S. Bungey of the South Australian Forest Service who carried out the field work and the greater part of the office work, and to Dr. F. C. Hummel for advice on the collection and preparation of the data.

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SOCIETY'S AND OTHER NEWS

HONOURS

To the names of members included in the 1956 New Year Honours list, as recorded in the last number of this journal, should be added that of Mr. Gilbert Brown, to whom we offer our congratulations. Mr. Brown was made O.B.E.

The distinction of Knighthood accorded Professor Champion in The Queen's Birthday Honours this year marks his great services to forestry and will give much satisfaction to his many friends both at home and abroad. We join them in offering him our congratulations.

CHANGE IN PUBLICATION DATE

With effect from the first number of volume XXX, the dates of publication of *Forestry* will be May and November. The next number of *Forestry* is not therefore due to appear until May 1957.

REVIEWS

Forestry Handbook. Edited for the Society of American Foresters by Reginald D. Forbes. Staff Editor, Arthur B. Meyer. New York. The Ronald Press Co. 1955. Price 15 dollars.

Review by W. E. Hiley

OUR sister society in America must be congratulated on bringing out this remarkable book. The first thing that strikes one about it is its size: more than 1,200 pages and, though many of them are filled with tables and figures, a page of straight text contains some 600 words. The book is too large to handle with comfort and it might have been better to make two volumes of it.

The text is divided into 23 sections which range in subject from Aerial Photography to Yield Tables and Stocking; and the pages and tables in each section are separately numbered. So it may be read as a collection of short textbooks, each of which has been prepared by an appointed committee. These committees constitute an 'editorial board of 145 consulting and contributing editors, including foresters, administrators, research workers and educators selected by the Society of American Foresters'.

The book is naturally designed to meet the needs of American foresters, and in America they are still in the main concerned with wild, or semi-wild, forests. The section on Forest Measurements, which is the longest in the book, is mainly concerned with estimating the volume for various uses which can be obtained from forests and, in addition to quoting representative log rule tables, it contains figures showing the approximate output of posts, ties, and other commodities. The next longest section is on Forest Range Management, 'rangelands' being defined as large, naturally vegetated, mostly unfenced, areas located in regions of low rainfall, which are grazed by domestic livestock and game animals. As there are 800 million acres of range lying between the Great Plains and the Pacific, their utilization is an important matter. Contiguous sections deal with Forest Wildlife Management, Watershed Management, and Forest Recreation.

The section on Logging contains much practical information, especially about vehicles and ropeways, that will be of value to British foresters, as Road Engineering presents the same problems in America as in Europe. 'Communications' gives more detailed instructions for operating telephone systems than is usual in books on forestry. Utilization is only lightly dealt with.

One could write endlessly about the wonderful information which this book contains, but to European foresters it is even more interesting to note how much that we consider important is omitted. It is significant that the bibliographies at the ends of the sections are almost confined to American literature, since it is by breaking loose from European traditions that they have become free to tackle their problems in a new and original manner. This fresh rooting of our basic knowledge of forestry in a virgin and fertile soil may eventually lead to very fruitful results, but in the meantime some of their conceptions appear to us as being rather crude and we are left with the impression that American forestry is still in the pioneering stage.

The section on Forest Management contains no less than 28 yield tables for various species, and the introduction of 'site indices' in place of 'quality classes' is an innovation which we should adopt. But none of these yield tables includes thinnings, and the figures

they provide refer to the stock of timber that may be found in unthinned stands of various ages. Thinning as a silvicultural operation is almost ignored throughout the book, and the only significant reference to it is in a seven-page subsection on 'Managing Forests for Christmas Tree Production'.

The expressions 'working plan' and 'sustained yield' do not occur in the index and I have found no reference to them in the book. The nearest approach to the conception of a working plan is contained in the section on Cutting Budget and Annual Cut, in which an 'endeavour to produce a regular flow of wood products' is an acknowledged objective. The section on Silvics and Silviculture contains very useful keys to American tree species, tables of silvicultural characteristics, and an instructive table of forest types abbreviated from an earlier publication by the Society. But silvicultural practice is dealt with in an elementary manner and one looks in vain for a representative description of their work on natural regeneration or, except for a valuable account of the use of fertilizers, their revolutionary methods of managing forest nurseries. The section on Economics and Finance is concerned with the appraisal and exploitation of existing forests but not with forest improvement as an investment.

Those who are acquainted with the progressive silvicultural developments—and the attendant research—which have originated in America may feel that this book does not give a fair picture of the fine work which American foresters are doing. Perhaps the aspects of American forestry in which European students are particularly interested constitute a very small part of the whole; or they may have wished to concentrate on those forests activities which are most profitable.

Forestry and Related Research in North America. By F. H. Kaufert and W. H. Cummings. Society of American Foresters, Mills Building, Washington. 1955. Pp. 280. Price 5 dollars

Review by H. L. Edlin

FOREST research in North America has become so vast an undertaking, carried on by so many different agencies, that the Society of American Foresters decided, in 1953, to make this appraisal of its scope, direction, and effectiveness during the preceding 25 years.

The agencies investigated include the Federal Government with its chain of research stations, certain of the individual States, many universities, and also industrial firms and organizations engaged in the processing of wood, paper pulp, and other forest products. The field of subjects reviewed extends beyond forestry and utilization into the 'forest-related' subjects of wild-life management both for sport and amenity, open-range grazing by livestock, watershed management to secure regulated water supplies for irrigation or domestic use, and the recreational use of woodlands. While there is an effective framework of statistics, particularly as regards expenditure, the findings are expressed in very readable prose, and the results deserve the attention of all who have to plan similar work, wherever they may be situated.

The day of the individual research worker making fundamental discoveries in his private study or laboratory are virtually over. Research today, particularly where it is concerned with trees that live longer than their students, calls for sustained teamwork, with a central continuing administration and assured funds. It requires a library and an elaborate system

of record-keeping, and must have available adequate media for the publication of its results. Areas for investigation or experiment in actual forests are also essential, since we can seldom reproduce a woodland environment within a laboratory. A further prerequisite for success is adequate contact with researchers in other fields of both pure and applied science, and both at home and abroad. Every forest research organization is thus both complex and expensive to operate, and its effective control and direction presents a study in itself.

Each country has to evolve a system of forest research appropriate to its particular social or economic structure. In one country the central forest authority may take the lead, as in Great Britain; in another, the universities may play a major part, with or without government support, as instanced by much fundamental work in Germany; or again associations like the Danish Heath Society may further pioneer afforestation projects that increase the sum of silvicultural knowledge. By whatever agency the discoveries are made, they soon become the common property of the scientific world through the varied media of international exchanges.

It is precisely on this point that the present book breaks down. Although Canada and Mexico are included, along with the United States, in its field of review, scarcely a word is said about any other country in the world. There is hardly a reference to the Food and Agriculture Organization of the United Nations. Overseas publications are completely ignored; there is no mention of *Unasylva*, nor of *Forestry Abstracts* which, as an English language review of world forestry literature, must surely be a useful means of communicating research results within America. One is left with the impression that American foresters, though inhabiting one of the largest continents, have developed an insular outlook on their subject matter; that they have little concern for the groundwork of forest science developed in Europe and Asia; and that most of them are unaware of its existence. We all know that North America is virtually self-sufficing in timber; here it is made to appear self-sufficient in science!

The Forester's Companion. By N. D. G. James. The Royal Forestry Society of England and Wales. Basil Blackwell, Oxford, 1955. Pp. 298. Price 12*s.* 6*d.* net.

Review by J. E. Garfitt

THIS book is published for the Royal Forestry Society of England and Wales whose President says in a Foreword that the Society 'has been for some time considering how best it might help British forestry and it was found that one long-felt need was for a book, small enough to fit into the pocket, which would give information in note-form, especially designed for the daily use and help of the working forester as he goes about his daily tasks'.

It is with this basic idea in mind, therefore, that the book must be assessed, and we may consider first its outward appearance and make-up. These are extremely good; the printing is of a high order, the type is attractive, the paper of good quality, and the binding satisfactory. But is it suitable for the pocket of a working forester, or for constant carrying in a satchel or even in a Land Rover? One would have liked to see it bound in stout canvas with an overlapping flap like the old Army Field Service Pocket Book.

In the contents Mr. James has covered all the headings under which forestry is usually considered and has added a large number of other chapters dealing with such diverse matters as Shelter Belts; Trees and the Law; the Forestry Commission; societies and organizations concerned with forestry; Botanic Gardens, Arboreta, &c.: Forestry Books and Periodicals; and many other special matters. The amount of information he has

accumulated is staggering and it is not perhaps surprising if some of this is somewhat esoteric, as when we are exhorted to finish transplanting hawthorn in January, or told that larks may eat our tree-seedlings. It is not surprising either to find expression of views which are those of Mr. James himself and not necessarily widely accepted, as when he states categorically that the 6-inch Ordnance map 'is not as useful in estate forestry as the 25-inch map'.

However, it is in the omissions that the book is weakest in its claim to be the working forester's *vade mecum*. Firstly the hoppus timber tables are represented by a paltry page, giving the contents of a lineal foot. Considering that these tables are referred to more often than any other publication by the majority of working foresters, this is a serious deficiency. One would have liked to see a condensed form of Wilson's desk edition of decimal hoppus tables, which would have enabled these tables to be concentrated into a reasonable number of closely printed pages. A somewhat amplified single-page 'Contents of a lineal foot' might have been provided in addition for the use of those employing the old feet, inches, and parts system. Space for these additions might have been made by omitting matters not of prime interest in the woods, such as consideration of the Forestry Commission's Plan of Operations forms (now obsolete).

A further omission is in the matter of rates of work. One is constantly concerned with speeds of work and piece-rates. Actual costings have no value when wages and costs are continually altering, but a table showing the number of man-hours required per unit of work completed for all the usual forestry operations would have been of the greatest value. Some figures are given but, except in the case of coppice-working, they are scattered and not sufficiently comprehensive.

It is in the Diseases and Pests section, however, that the greatest disappointment lies. If it is to be of use to the man in the field such a section should be so complete that no disease liable to be met in the forest is omitted. Here we have only twenty fungus diseases listed for both broadleaved and coniferous trees, and one of those is the interestingly new but unimportant Sooty Bark Disease of sycamore. This is useless to a forester faced with the identification of a disease in the forest. The insect pest section is better arranged and more comprehensive, but it is barely adequate when it is seen that only 29 species are listed against some 150 species in Dr. Chrystal's *Insects of the British Woodlands*. Incidentally it was in this chapter that a few misprints were noted among the specific names.

However, the reviewer's reaction to a perusal of this mass of classified information must be that here is a book of the greatest value to working foresters. It sets out to do, and accomplishes, what no earlier publication has done, in providing information in a condensed form for the use of the man in the forest. That it can be improved there is no doubt; that it will be in the many future editions it deserves is confidently expected. In the meantime it can be recommended to all concerned with woodlands as a very handy reference book, and to working foresters as a guide to further information on almost any forestry subject that may arouse their interest. The Royal Forestry Society and Mr. James are to be congratulated on a most useful production.

The Law of Forestry. By W. A. Gordon. H.M.S.O. 1955. Pp. 574. Price £3. 10*s*.

Review by B. C. Adkin

ACCORDING to the title-page this book is published for the Colonial Office but more than half of it is given to the law in Britain. It seems that no book of so wide a scope has before been issued. In recent years there has been a considerable increase in the number

of books on various aspects of British forestry but on the law there has been none since *The Law of Forestry* by B. W. Adkin was published in 1914, and that was the first after Manwood's *Forest Laws* of 1665. A legal commentary which would incorporate the modern law of real property and the various statutes passed since the formation of the Forestry Commission was therefore to be desired.

The author is an Oxford graduate in forestry, a barrister-at-law, and has had administrative experience as a forester. That he is well qualified for the task is also evident from the support he has had in undertaking it, and he has had the assistance of other experts in certain chapters. Two short ones on the Scottish law are written by Mr. A. J. MacKenzie Stuart. It should be said that the book was completed in 1951, and although nothing of major importance to the subject has appeared since, one can feel sympathy with the author that publication has been so long delayed.

A glance at the authorities which the author quotes with regard to the various parts of the subject gives confidence in the soundness of his matter, and this confidence is confirmed and enhanced on reading, by his style, his comprehensive grasp of the subject in hand, and well-balanced treatment. Much trouble has been taken in collecting and summarizing cases in the Courts which interpret and develop the law with regard to certain circumstances. The author's comments are interesting. Professor Lawson, in an introduction, praises his way of discussing, historically, as well as practically, the policy behind the various statutes, and adds that it is not often one finds such discussion in books on technical branches of law.

The book is divided into four parts. The first deals with such general principles of law as the author says he has found it convenient to remember in the course of his experience as a forester. It is as a lawyer that he has been able to make such a reliable and appropriate selection. The chapter on contract needs revision in view of the repeal of important statutory provisions in 1954; but footnotes refer to this. 'The Law of Forestry in Britain' is the subject of Part II. The old royal forests are dealt with in detail but more space is rightly given to private woodlands. The incidence of the national taxes on the latter is very usefully described. The section on local rates, however, is relatively short. Although a rating authority is not likely to invoke the Rating Act, 1874, it is still law and its peculiar provisions are not given. The remarks on the rating of sporting rights over woodlands might be expanded with advantage.

The Forestry Acts, 1919–51, form a separate section and they are printed in full with comments. It is good to see the by-laws under the Act of 1927; they should be more widely known. Dedication is described as fully as it could be at the time of writing. Unfortunately the author did not have time to consider the Act of 1951, or relate it to previous chapters, as fully as he would have wished.

Part III relates to 'Forest Law in the Colonies'. It includes general chapters on English and Colonial law, prevalent forms of land abuse, forest reservation, protection and forms of colonial forest legislation, as well as special chapters on the various colonies. The texts of colonial forest Acts are given in an appendix. All this part should be of great value to those concerned.

Anyone who is interested will find much to learn in this book and pleasure in doing so. It may also be recommended as a reliable work of reference and the index, after considerable testing, has been found adequate for the purpose. Not only foresters but landowners and their agents should have the book, and it is hoped that a demand for another edition will enable the author to revise certain chapters and to help us with further developments of his subject.

NOTICES

Division of Scotland into Climatic Sub-Regions as an Aid to Silviculture. By M. L. Anderson and W. A. Fairbairn. Bulletin No. 1 of the Forestry Department, University of Edinburgh. 1955. Pp. 31 with 4 maps and 2 figures. Price 10*s*.

SOME relatively simple division of Scotland into sub-regions in which the major factors are likely to differ sufficiently to require modification of silvicultural technique was needed firstly to assist in determining, within Scotland itself, the location of areas in which choice of species and of methods should be similar; and secondly to aid in correlating the sub-regions in Scotland with similar divisions in other countries from which it may be desirable to introduce particular tree species, or strains of tree species, or methods of silviculture, which have been more fully tested there.

The choice between major factors of climate, geology, or of soils had to be made and it was felt that the primary basis in Scotland must be climatic. After trying various procedures, and after considering that it would be unreal to employ any formula, it was decided simply to combine a zonation into growing-season temperature zones, with a zonation into growing-season rainfall zones. The authors note that it is by no means easy to form climatic sub-regions by combining two factors only but it is nearly impossible to combine more than two factors. Some brief account of how it was done and of the allowances made for other important factors are given below.

The determination of the temperature factor follows closely the method adopted for similar purposes by Hagem in Norway. This is based on tree behaviour, i.e. the leaf-flush of the birch, and is taken as the number of days which lie between the first day of spring, whose mean temperature rises to 45° F., and the first day of autumn, whose mean temperature fails to reach 45° F. The method adopted to record the length of the growing season for any meteorological station is simple enough and is shown in graphs in the bulletin, but the map of Scotland resulting from this and showing the zones of length of growing season in days from 210 to 160 makes it plain that altitude is not the only factor affecting the temperature and thus length of growing season. It appeared to the authors that if this other factor, or combination of factors, were to display less marked variation than altitude, it might prove to be a more useful basis for temperature zonation than the actual growing season lengths influenced by altitude. It was therefore decided to eliminate the altitude by allowing a fall of 1° F. for every rise of 300 feet, and a map was prepared to show 4 zones of growing season lengths adjusted to sea-level (map 2). Growing season rainfall was then determined taking the 5 months of May to September inclusive, classified into 4 zones with a mean growing season rainfall of less than 15 inches, 15 to 20 inches, 20 to 30 inches, and over 30 inches (map 3). The next step was to superimpose the four growing-seasons rainfall zones over the four length of growing-season zones to give 14 climatic sub-regions or sub-provinces (there is some confusion here over the nomenclature). These were not self-contained but consisted of 47 districts unrelated to topographical features. For practical reasons, it was decided to alter the smoothed lines drawn on maps 2 and 3 to agree with recognizable topographical features. The resulting map (map 4) gives 14 climatic sub-provinces and 47 districts. Details of the boundaries are given in an appendix. Supplementary climatic information such as frost, sunshine, cloud, humidity, and exposure is given for each in a table. There is a note and a table on the effect of altitude on growing-season within sub-regions. Notes on geology are given in an appendix.

For fuller details, and for the actual zonation, the Bulletin must be consulted. The authors disclaim any intention of dealing with the climate of Scotland as a whole but merely —as they say—make a rather mechanical use of the meteorological information available to serve their purpose. They describe the Bulletin as an attempt at climatic mapping which 'should for a time take the place of the existing rather crude classifications we have hitherto had to rely on'.

Man and the Land. By L. Dudley Stamp. Collins. 1955. Pp. 272. Price 25*s.* net.

Trees, Woods and Man. By H. L. Edlin. Collins. 1956. Pp. 272. Price 30*s.* net.

The Influence of Man and Animals on the Vegetation of Certain Hill Grazings in South East (and in Mid-East) Scotland. By E. Wyllie Fenton. Bulletins Nos. 4, 5, and 7 of the Edinburgh and East Scotland College of Agriculture. 1951–3. Many aerial photographs. Price not stated.

THE first two books are respectively numbers 31 and 32 in the New Naturalist Series and, like other books in this series, are illustrated with photographs both in colour and in black and white.

Dr. Stamp's book is a sequel to his earlier book in this same series, the excellent *Britain's Structure and Scenery* published in 1946, and he has in *Man and the Land*, as he states in his preface, trespassed into many specialist fields in order to complete his story of the elimination of wild nature at the hand of man over the ages. While this too is a good book, the method of compilation makes it rather uneven and it does contain some inaccuracies which, though unimportant, do rather detract from its value.

In his preface to *Trees, Woods and Man*, Mr. Edlin says that he has sought to review the position of trees and forests in the life and landscape of Britain from the standpoint of the inquiring layman rather than from that of the professional forester. Trees can hardly be considered without regard to their past, and the nine hundred years since Rufus is but a chapter in the full history of the British woodlands which suffered beneath the stone axes and the hoes of Neolithic settlers three thousand years before the Normans came and whose origins can be set seven thousand years earlier still. The present distribution of our woods can only be understood by reference to past agricultural practices and needs, when it will be realized how scant is the natural woodland that is left. Hence the title of the book and its structure.

The first five chapters, comprising Part I, are concerned with the natural history or biology of trees alone, considered as though growing in an environment uninfluenced by man's work. In Part II the first four chapters unfold the story of man's growing influence on the woodlands, and his increasing care for their welfare, while in the fifth chapter we explore his philosophy towards them. Against this background the stories of the more important kinds of trees, or groups of trees, are recounted in the fourteen chapters that make up Part III. Although written independently, Mr. Edlin's book may be considered as an extension of *Man and the Land* within the realms of the forest.

Dr. Fenton shows how rural depopulation, selective grazing by sheep, and the absence of shelter either for man or for beast are some of the many causes which account for the sorry state of much of the hill grazing lands in parts of Scotland. He stresses the value of birch both for shelter and as a soil improver and would like to see patches of woodland made not primarily for forests but for protection in the more exposed grazings. With reference to Blair Atholl and Struan, the author quotes from the Second Statistical Account to show that at the beginning of the nineteenth century agriculture was already in retreat.

'On the summits of the high mountains, the weather has left little else than gravel and stones, covered with moss. This part is called Creachonn (creachthonn), i.e. robbed land, the soil having been blown, or washed away, a good way down the sides. Further down is heath, ava urse, the Craw-berry plant; on mossy or boggy places the Cloudberry plant; and on drier ground, the Wortle-berry-bush, with coarse grass. Lower down is heath, peat-bog, valleys full of pretty good pasture, and here and there a green spot with huts upon them; to which the women, children and herds retire with the cattle for the summer season. Descending still further down, the air and soil generally change for the better; but in some places, the hills within sight of the river are stony and bad. The vestiges of the plough are often seen much higher up than it goes at present: probably because the wood made higher places warmer, and much of the bottom was a thicket, etc.'

Profitable Forestry. By Lord Bolton. Faber & Faber Ltd., 1956. Pp. 123 with line illustrations and plates. 9 inches by 5½ inches. Price 15*s.* net.

LORD BOLTON'S stimulating book is addressed to the woodland owner. He is not concerned with detail but sets down 'those rules of forestry . . . essential to the proper and profitable management of woodlands and he maintains that there is hardly an estate that, under good management, cannot show an appreciable and regular profit. There is a good chapter on the choice of species which he emphasizes is 'the fundamental basis of successful forestry'. Another on thinning which should be 'early, often, and drastic'. Possibly most valuable of all is the chapter on marketing which 'first, last and all the time is the secret of profitable forestry'.

Forestry. By T. A. Robbie. English Universities Press Ltd., 1955. Pp. 189 with line illustrations. 7 inches by 4½ inches. Price 6*s.* net.

MR. ROBBIE'S book is one of the 'Teach Yourself' series and introduces the reader to the science and industry of forestry and leads him through the sequence of work undertaken in the woods, explaining the why and the wherefore of the work done. As befitting a book written by the chief instructor Faskally forester training school, the book will be of great value to students. It should be very usefel too to the visitor to forestry centres in Britain who wants to know what is being done there and why, and should help to promote appreciation and understanding.

What wood is that? By A. Schwankl. Translated, with a preface, by H. L. Edlin. Thames and Hudson Ltd., London, 1956, Pp. 164 with numerous photographs and drawings and 40 actual wood specimens. 8 inches by 5¾ inches. Price 25*s.* net.

THIRTY out of forty of the trees whose timber is included in the collection are hardy in Britain. The approach throughout is direct and practical and care has been taken with the editing to ensure that the details set down accord with British practice. This is a fascinating book and should increase lay interest in wood and its uses.

continued from inside front cover]

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